1995

Cost analysis of recapitalizing Marine light attack helicopter assets: a case study

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http://hdl.handle.net/10945/31281

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

COST ANALYSIS OF RECAPITALIZING MARINE LIGHT ATTACK HELICOPTER ASSETS: A CASE STUDY

by

Conrad Nelson Brown, Jr.

December, 1995

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REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE December 1995	3. REPORT TYPE AND DATES COVERED Master's Thesis

4. TITLE AND SUBTITLE COST ANALYSIS OF RECAPITALIZING MARINE LIGHT ATTACK HELICOPTER ASSETS: A CASE STUDY	5. FUNDING NUMBERS
6. AUTHOR(S) Brown, Conrad N.	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey CA 93943-5000	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited	12b. DISTRIBUTION CODE

13. ABSTRACT *(maximum 200 words)* *This thesis focuses on the development of a spreadsheet model that can be used by acquisition personnel to forecast the life-cycle costs of a weapon system under consideration for acquisition, helicopters for Marine Light Attack Helicopter Squadrons, which provides the basis for the model. The life-cycle costs used are limited to the cost of operating and supporting the system once it has been deployed and represent the most significant costs incurred during the system's life-cycle. In an effort to assist the Program Manager in the decision-making process, decision analysis techniques are introduced. An "add-in" simulation software package allows the assumptions upon which the cost-estimates are based to take on a more realistic stochastic nature. From the simulation trial runs, distribution frequencies are generated which enable the cost analyst to establish a future cost with a higher probability of occurrence. Cost sensitivity analysis is also used to provide the Program Manger with a mechanism for establishing which assumptions have the greatest impact on costs and what happens when those assumptions are varied. The major finding of the theses is that these decision analysis techniques can significantly aid the Program Manager in the decision-making process.*

14. SUBJECT TERMS NAVAIR, Defense Systems Acquisitions, Cost-Estimation, Spreadsheet Modeling, Decision Analysis Techniques	15. NUMBER OF PAGES 138
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

Approved for public release; distribution is unlimited

COST ANALYSIS OF RECAPITALIZING MARINE LIGHT ATTACK HELICOPTER ASSETS: A CASE STUDY

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Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
December 1995

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ABSTRACT

This thesis focuses on the development of a spreadsheet model that can be used by acquisition personnel to forecast the life-cycle costs of a weapon system under consideration for acquisition. It involves a case study of a major weapon system acquisition, helicopters for Marine Light Attack Helicopter Squadrons, which provides the basis for the model. The life-cycle costs used are limited to the cost of operating and supporting the system once it has been deployed and represent the most significant costs incurred during the system's life-cycle. In an effort to assist the Program Manager in the decision-making process, decision analysis techniques are introduced. An "add-in" simulation software package allows the assumptions upon which the cost-estimates are based to take on a more realistic stochastic nature. From the simulation trial runs, distribution frequencies are generated which enable the cost analyst to establish a future cost with a higher probability of occurrence. Cost sensitivity analysis is also used to provide the Program Manager with a mechanism for establishing which assumptions have the greatest impact on costs and what happens when those assumptions are varied. The major finding of the thesis is that these decision analysis techniques can significantly aid the Program Manager in the decision-making process.

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LIST OF ABBREVIATIONS, ACRONYMS, AND/OR SYMBOLS

ACAT	acquisition category
CAE	component acqusition executive
COEA	cost and operational effectiveness analysis
DAE	defense acquisition executive
DODI	Department of Defense Instruction
DODM	Department of Defense Manual
FMFM	Fleet Marine Force Manual
HMLA	Marine Light Attack Helicopter Squadron
LCC	life-cycle cost
MAGTF	Marine Air-Ground Task Force
MCCDC	Marine Corps Combat Development Center
ORD	operational requirements document
O&S	operations and support
NAVAIR	Naval Air Systems Command
NOE	nap-of-the-earth
MOS	military occupational specialty
PEO	program executive officer
PM	program manager
P^3I	pre-planned product improvement
ROM	rough order of magnitude
R&D	research and development
SAR	search and rescue
SDLM	standard depot level maintenance
SLEP	service life extension program
SPIE	special purpose insertion/extraction
TOW	tube-launched, optically-tracked, wire-guided

I. INTRODUCTION

A. GENERAL OVERVIEW

The official end of the Cold War was decisively punctuated by the resultant downsizing of America's military due to the disappearance of the ominous global threat and all of its associated military requirements. But the outcomes of the Cold War's end had far greater implications than were first realized. Probably the most obvious outcome was the decrease in funding levels for current and future military programs. As the DoD drawdown continues, competition for scarce resources becomes an ever-increasing concern for not only DoD as a whole, but also for the individual military services. However, with the absence of the global threat as a measurement tool, military force planners are faced with much more uncertainty now than they had before. The uncertainty arises predominantly out of lack of information on potential threats in the regional arenas. Force planning today is more "uncertainty-pulled" vice "threat-driven" which results in a greater need for flexible forces.[1]

This emphasis on flexibility and its underlying assumptions are not going to disappear anytime soon. Flexibility has become the key to accomplishing our strategic objectives in the future. But, this flexibility does not come without a price. Greater flexibility in this case translates into forces requiring rapid deployment,

massive air lift, and mobile, high-firepower systems which will almost certainly result in increased cost.[2]

Historically, the forward deployed Marine Air-Ground Task Force (MAGTF) has been our nation's first response to crisis situations throughout the world. The MAGTF concept has traditionally provided the flexibility necessary to counter many different threats. The overall concept is based on "a combined arms organization structured to exploit the synergy inherent in closely integrated air and ground operations."[3] A key element of the MAGTF's intrinsic flexibility rests in the Marine Light Attack Helicopter Squadron (HMLA).

The mission of the HMLA is to provide utility helicopter support, attack helicopter fire support, and fire support coordination during amphibious operations and subsequent operations ashore.[4] Currently, the squadron's assets include both attack and light assault (utility) helicopters to perform this mission. Through the versatility of the squadron's assets, the HMLAs have provided the MAGTF commander with a degree of flexibility that can not be achieved by other economic means. The weapons load on the attack helicopter, for instance, is very adaptable and can be tailor-made for the task at hand. However, the emerging Navy and Marine Corps doctrine, called Forward... From the Sea, is changing the employment concepts of the squadron and their aircraft.

Currently, HMLAs operate the Bell Helicopter, AH-1W Cobra in the attack role and the UH-1N Huey in the light

assault role. The squadrons have operated some variant of these aircraft since the 1960s. The existing AH-1W fleet consists of a mix of modified AH-1Ts, which first entered service in 1977, subsequently upgraded to the AH-1W configuration and also new production AH-1Ws which were first delivered in 1986. The aging UH-1N fleet is composed of utility helicopters which first entered service during the Vietnam Conflict. This aging of the airframes has resulted in inadequate performance on the part of the Huey and a limit in the future flexibility of the Cobra.

New, emerging Marine Corps policies dictate that systems should be streamlined, modernized, and simplified without any appreciable loss of capabilities. This has forged the way for a logical necking down of Marine aviation assets from the current nine different types of aircraft in operation to just three. A strategy was crafted to accomplish this as efficiently and effectively as possible. The plan included the procurement of a vertical take-off aircraft (VMAO) that would fill the attack, utility, and observation roles while having flight characteristics compatible with the MV-22. However, due to fiscal constraints created by the procurement of the MV-22, F/A-18 E/F, and other, higher priority aviation programs, the development and procurement of VMAO was deferred until 2020.[5]

In light of the aging fleet and new concepts of operation, military planners were forced to analyze these effects on operational effectiveness. The overall

conclusion was that a recapitalization of HMLA assets was necessary to ensure that the required capabilities could still be maintained into the 21st century. Current forecasts reveal that at the present rate of losses suffered due to mishaps during both peacetime and operational missions, the Marine Corps' assets will fall short of the required force structure prior to fielding of a replacement aircraft in 2020. Furthermore, there are safety and performance issues that compound the effects of the declining inventory that must also be taken into account. In order to maintain its warfighting capabilities, it seems clear that the Marine Corps must develop a strategy to bridge the gap to 2020. In addition, the effects of funding constraints and service life issues must be an integral part in the crafting of the strategy.

B. PROBLEM STATEMENT

In the past several years, there has been a virtual explosion in the use of analytical techniques in the field of management. This development is due, in part, to the advent of powerful microcomputers and also to the increasingly complex environments in which we operate. As the environment becomes increasingly more complex, decision-makers are forced to become more sophisticated in their decision-making processes. These sophisticated analytical techniques, which includes regression analysis, time-series analysis, and simulation, are changing the face

of decision-making. New real world applications are literally cropping up everyday. Where ever there is a need to make decisions in an atmosphere of less than perfect information, these analytical techniques may provide the necessary tools to make the most informed decision possible.

The DoD acquisition process allows the mission needs of the user to be transformed into a weapon system that is affordable, supportable, reliable, and most of all, meets the needs of the user. These needs are translated into performance requirements that the system must meet or exceed, balanced against some specified cost constraint. The cost of acquiring the system must be actively managed to ensure the lowest total cost possible. However, there are probably several different systems or concepts that could both meet the target performance requirements and the specified cost. So, how is the choice made between these alternative systems? Or more importantly, can these decision analysis techniques briefly discussed above assist the Program Manager (PM) in his ultimate task of choosing the right system?

This thesis is a case study which provides an in-depth analysis into the recapitalization of the HMLA assets. The focus is on providing the PM with additional decision support tools to allow him to choose the most cost-effective means of bridging the gap until a replacement aircraft is fielded in 2020. This particular case was chosen for two reasons: First, the program is in a rather early stage of the acquisition cycle which allows whatever lessons are

learned in this thesis to still be applied: and, second, the rather unique alternative strategy of common components to reduce costs poses an especially complex issue.

The objective of this thesis is to construct a simple forecasting model to facilitate the use of decision analysis techniques in an effort to provide data on the alternative systems to support a decision to acquire or not acquire. The model will be able to assist the analyst by taking all quantifiable factors into consideration and forecasting their impact on the process some time in the future. The results of each alternative can then be compared and the final choice made.

The remainder of this thesis will explore the acquisition process and how decisions are currently made. The results of NAVAIR's current method will be contrasted against the results of the model. A brief overview of the acquisition process is included to give the reader an appreciation for the complexity of the process. A discussion on the alternative systems follows.

C. ATTACK HELICOPTER BACKGROUND INFORMATION

The AH-1W Cobra is a twin-engine, two-bladed, tandem-seated, conventional helicopter capable of delivering a host of armament including the optically-tracked wire-guided TOW anti-tank missile, the laser-guided HELLFIRE anti-tank missile, and the infrared-guided anti-aircraft SIDEWINDER missile. It is an aggressive high-speed

helicopter built around its required combat mission. The mission spectrum covers the air-to-air environment through the air-to-ground environment with multiple weapon suppressive fire. The primary mission is that of an armed tactical helicopter, capable of search and target acquisition, low altitude high-speed flight, multiple weapon fire support, reconnaissance by fire, and troop helicopter support. The helicopter is capable of performing these missions during day or night conditions and periods of reduced visibility, operating from both prepared and unprepared surfaces.

The helicopter first saw combat as an AH-1J twin-engine variant of the Army's AH-1G Cobra. The thinking of the era called for an aircraft that could support ground forces with a variety of armament, yet still maintain some measure of survivability. The AH-1J was then modified to the TOW missile variant, the AH-1T. Over time, the AH-1T had grown in weight due to the addition of various systems/subsystems that were effectively "bolted on", in contrast to a systems-integrated approach. Additionally, Nap-of-the-earth (NOE) flight tactics and the expansion of the Marine Corps role in high-elevation, hot geographical areas, had exceeded the limited horsepower that was available in the AH-1T.

The latest variant to be fielded, as noted above, is the AH-1W Super Cobra. This aircraft is powered by two General Electric T700 engines capable of producing up to 1690 shaft horsepower each. On 20 June 1994, the Marine Corps fielded its first new-production AH-1W with the

built-in night targeting system. Developed by Tamam Industries of Israel, the upgrade was the first phase in a series of planned upgrades to the AH-1W system. Currently, there are two more phases planned but not yet funded. The next phase includes an upgraded cockpit with multifunction digital display technology replacing the present analog gauges. The final upgrade revolves around a four-bladed rotor system that would dramatically increase the performance of the AH-1W.

The alternative systems under consideration for filling the attack role are the AH-64D Apache and the RAH-66 Comanche. An aircraft overview is contained in Appendix B which compares key performance issues and costs. The Apache is a production model airframe that has been in operation with the U.S. Army. As can be seen from the cost chart in Appendix B, the production cost of this aircraft is close to the total cost of another alternative. The Comanche is still in the developmental stage with many unknowns. The conclusion on the attack helicopter was reached fairly quickly. The Comanche's performance is comparable to the four-bladed Cobra, but with a higher production cost. The Apache's performance is also comparable to the four-bladed Cobra, but with a much higher cost.

D. LIGHT ASSAULT HELICOPTER BACKGROUND INFORMATION

The UH-1N Huey is a twin-engine, two-bladed utility helicopter capable of operating from prepared or unprepared

surfaces, under both day and night conditions and during periods of reduced visibility. The helicopter can support a full gamut of tactical missions including visual reconnaissance, command and control, artillery observation and spotting, paratroop and rappelling operations, Special Purpose Insertion and Extraction (SPIE) rigging, and search and rescue (SAR). The airborne observation role has grown out of the recent retirement of the OV-10 Bronco at the close of Operation Desert Storm in 1991.

The UH-1N helicopter is a Vietnam-era aircraft with an average age of 23 years and some 6,000 to 7,000 hours of flight time logged per airframe.[6] This is beyond the planned useful life of the airframe. The age and hours on the airframes have resulted in degraded capabilities and performance. "Mission creep" has also been a factor in the Huey's reduced ability to perform. Mission creep occurs when, over the years, the weight of additional equipment and systems used for missions which the airframe was not originally designed for, is not compensated for by a corresponding increase in aircraft performance.

Due to fiscal constraints, there is currently no funding available for a "New Start" replacement to the UH-1N. However, with the aircraft no longer in production and an annual attrition rate of 2.3 percent, it is now estimated that the current Huey fleet will fall below the Marine Corps' requirements by the year 2002.[7] By that time, it is estimated that the Marine Corps will need 10 additional Hueys to meet its mission requirements. These

aircraft would probably have to be transferred from the Navy.

A service life extension program (SLEP) has been planned to begin in 1997 to extend the life of 105 Marine UH-1Ns to 17,500 hours of flight. A service-life-assessment- program is set to begin this year in an effort to determine what the service life extension and upgrades will actually entail. The current planned upgrades include: a four-bladed rotor system, upgraded engines, and an improved drivetrain. If these components are identical to the Cobra components, then a significant cost-savings can be realized across the entire life-cycle. These common components would include structures, flight controls, engines, drivetrain and drive systems. The current estimates on the savings "hover" around 20 to 30 percent versus the acquisition of a new system to replace the UH-1N.[8]

The light assault alternatives are much more competitive in respect to cost and performance. The alternatives to the attack role were clearly not as good a choice as the four-bladed Cobra. However, due to the common component strategy, the costs incurred by one aircraft will undoubtedly have effects on the other. This makes this acquisition environment especially complex.

The UH-60 Blackhawk and the variant HH-60H Seahawk are both production light assault helicopters. The Seahawk is in operation with the U. S. Navy and the Blackhawk is in operation with the U. S. Army. The key performance issues

and estimated cost data are also included in Appendix B. The acquisition of this system would result in a modification of an existing system to fulfill the unique needs of the Marine Corps. From the chart, it can be seen that the performance of the H-60 variants is slightly better than the four-bladed Huey at an increased cost. In fact, due to lack of data cost-estimates for the total cost of these systems has not yet been made.

E. LITERATURE REVIEW

Department of Defense Instruction (DoDI) 5000.2, *Defense Acquisition Management Policies and Procedures* and Department of Defense Manual (DoDM) 5000.2-M, *Defense Acquisition Management Documentation and Reports*, are used as the doctrinal basis for all defense acquisition policies and principles. *Cost Realism Handbook,* published by the Navy Office for Acquisition Research, is used as basis for evaluating estimated costs. Defense Systems Management College publication, *Integrated Logistics Support Guide,* provides the necessary understanding of logistic support and life-cycle costs. *Regression Techniques for Managerial Planning and Control*, authored by Shu S. Liao, was used as the primary reference for decision analysis techniques.

Reference data is collected primarily from Naval Air Systems Command, Program Management Office, Code PMA-276, and from interviews with personnel from Marine Aircraft Group 39, Marine Corps Air Station, Camp Pendleton, CA.

F. THESIS ORGANIZATION

The thesis is organized into six separate chapters and six appendices. Chapter II outlines and discusses the defense systems acquisitions process. Special emphasis is placed on developing an appreciation for the difficulty and complexity of bringing a major weapon system to the user. Acquisition strategies to include pre-planned product improvement, major upgrades to existing systems, and common components is discussed. This discussion provides the basis for identifying and analyzing the relevant areas of the system life-cycle upon which the cost estimations will be based. Chapter III provides an overview of cost estimation methods and forecasting techniques in use today. The chapter attempts to forge common ground for the assessment of the current cost-estimates used by Naval Air Systems Command (NAVAIR).

Chapter IV discusses the life-cycle elements identified in Chapter II as they relate to costs. The current cost estimates used by NAVAIR are assessed for completeness and the data generated are validated. The estimates may need to be adjusted to incorporate any new elements which were previously overlooked. New data would then be generated for analysis.

Chapter V discusses the costs analysis and relates the costs-estimates of NAVAIR to the cost-estimates derived from a model based on NAVAIR-generated data. A comparison of the costs is conducted along with a discussion on the model.

Chapter VI discusses the conclusions and recommendations of the analysis. The chapter closes with a recommended area for further investigation into the use of computer-based modeling and decision analysis techniques as a basis for future evaluation of competing alternatives.

Appendix A is a glossary of commonly-used terms broken down into two sections. The first section contains acronyms and abbreviations, the second section contains definitions, which whenever possible, are Department of the Defense standard definitions. Appendix B contains the Aircraft Overviews and cost data. Appendix C contains the Operation and Support Cost Element Breakdown Structure. Appendix D contains the Life-Cycle Cost Assumptions. Appendix E contains the NAVAIR LCC Estimates. Appendix F contains the model and the forecast data.

II. DEFENSE SYSTEMS ACQUISITION AND PROGRAM MANAGEMENT

A. ACQUISITION PROCESS OVERVIEW

The acquisition of defense systems is a very complex and detail-oriented process which provides a logical means of translating broadly-stated mission needs into well-defined system-specific requirements.[9] These requirements are then transformed into a weapon system that is affordable, logistically supportable, and meets the needs of the user. The process uses a strategic management approach of incremental commitment of resources, while decreasing overall risk.[10] The following sections of this chapter attempt to give a very fundamental and abbreviated version of the acquisition and program management process, focusing on key elements that are crucial to understanding the remaining chapters of this thesis.

Acquisition programs are managed from a structure that is separate from the normal operational chains of command. An acquisition program is described as "a directed, funded effort that is designed to provide a new or improved material capability in response to a validated need."[11] In order to grasp how this process works, an introduction to the key players is essential. The key players in the acquisition process are the program manager (PM), the program executive officer (PEO), the component or service

acquisition executive (CAE), and the defense acquisition executive (DAE). The relationship between the players is illustrated in the organizational chart shown in Figure 1.

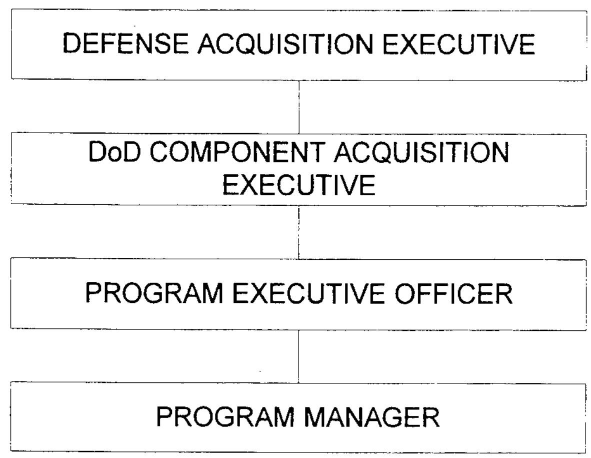


Figure 1. Program Management Hierarchy

The Program Manager is central to the acquisition process and is responsible for ensuring that the weapon system meets the performance requirements necessary to satisfy the user's needs, proceeds on schedule, within specified budget constraints, and is logistically supportable.[12] The program manager develops an acquisition strategy, plans out the program by generating the management approach to include: budgetary estimates and alternatives, program schedules, and day-to-day management of the program. The relevant elements of program management will be deferred

to a later section in the chapter. Let us first discuss the acquisition process and how the key players fit into it.

Defense systems acquisitions is broadly divided into two distinct functions: those functions necessary for the preparation of acquisitions and the formal acquisition. The preparatory area consists of mission needs, requirements determination, and concept exploration and will be discussed in the next section of this chapter.

The formal acquisition process is broken down into five major milestone decision points and five separate phases of acquisition as illustrated below in Figure 2.[13] Normally, a program proceeds along this "text book" milestone line beginning with the identification of mission needs and progressing through the Operations and Support Phase. This encompasses the life-cycle of the system from its point of inception to its planned disposal. It must be pointed out that not all acquisitions fit neatly into this progression. If several early steps can be omitted, abbreviated, or combined, significant cost and time savings can occur. It should also be pointed out, that the Concept Exploration and Definition Phase is really preparatory in nature since technically, the program is not formally established until Milestone I, Concept Demonstration Approval. The implications of each of these milestones and phases will be discussed in greater detail later in this chapter.

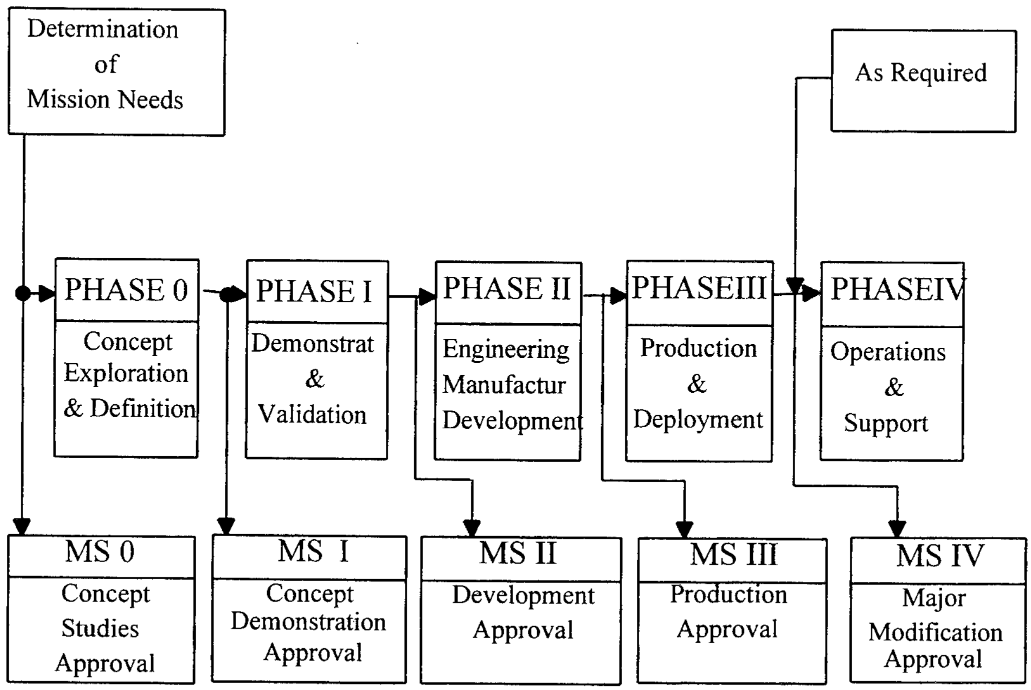


Figure 2. Milestone Decisions and Acquisition Phases

B. MISSION NEEDS

It can be argued that the complex world of defense systems acquisitions begins with a mission need or requirement from the "user". This mission need is often the result of an intense analysis of a potential enemy's current or projected capabilities compared to that of the user. Threat analysis is a very important element in acquisitions. Without a bonafide, threat there would be no need to acquire a new weapon system. A validated threat assessment is necessary at each milestone decision point and is just one

of the criteria that must be met prior to the program continuing on to the next phase. This is by design, since the time element of bringing some of these systems to market can span several years, during which time, the threat may change or even cease to exist.

The Mission Needs Statement may be prepared by any DoD component which has identified a specific mission area need or deficiency. The Mission Need Statement is then submitted to the operational validation authority for evaluation and validation. For mission needs that could potentially result in a major defense acquisition program (acquisition category I or ACAT I), the Mission Need Statement will be submitted to the Joint Requirements Oversight Council (JROC) for review and validation.[14]

It must be recognized that every mission need does not automatically result in the new acquisition of a weapon system. As previously alluded, this path would prove to costly and therefore, identified mission needs are first evaluated to determine if they can be satisfied by some non-material solution. Non-material solutions are usually in the form of changes in doctrine, tactics, operations, concepts, training, and/or organization. These solutions may be viable and most likely represent the least costly approach. Once it has been determined that an identified need cannot be satisfied by non-material means, a hardware option is then considered. The mission need is then expressed as a broad-based operational capability as opposed to a system-specific solution and is prioritized relative to

other documented needs. The broad-based operational capability enables us to refrain from being locked into a single solution and paves the way for the initiation of study efforts of alternative concepts. This occurs during Milestone 0, Concept studies Approval.

Once the minimum set of alternative concepts to be studied is defined, the acquisition moves on to the Concept Exploration and Definition Phase (Phase 0). Various alternative concepts are explored in a host of studies and initial testing is accomplished to determine which concepts are the most feasible. The Cost and Operational Effectiveness Analysis (COEA) is accomplished to provide an analytical basis which allows a comparison of the alternative concepts on the basis of cost and operational effectiveness. An Operational Requirements Document (ORD) is generated for each concept that is set to progress to the next phase. The ORD contains the performance and operational parameters for these proposed alternative concepts. This represents the preparatory phase of the acquisition process. We will now turn our attention to the formal acquisition process and elaborate on just how systems are developed and procured.

C. FORMAL ACQUISITION PROCESS

Milestone Decision I authorizes the start of Phase I, Demonstration and Validation (DEM/VAL) and also establishes the requirements for the phase. Now that the alternatives

have been narrowed down by previous efforts, the system is looked at closely in terms of performance, cost, schedule, and supportability.[15] Multiple designs and parallel technologies may still be pursued, however, only the most promising solutions will be explored. Prototyping is now begun and the acquisition strategy is prepared. Life-cycle cost analyses are performed to identify and evaluate cost drivers and the impact on the overall system cost. It is important to note that the life-cycle cost concerns are built into the process in the early stages. The operating and support costs have a rather large impact on the overall cost as depicted in Figure 3. Life-cycle costs will be fully discussed in a later chapter.

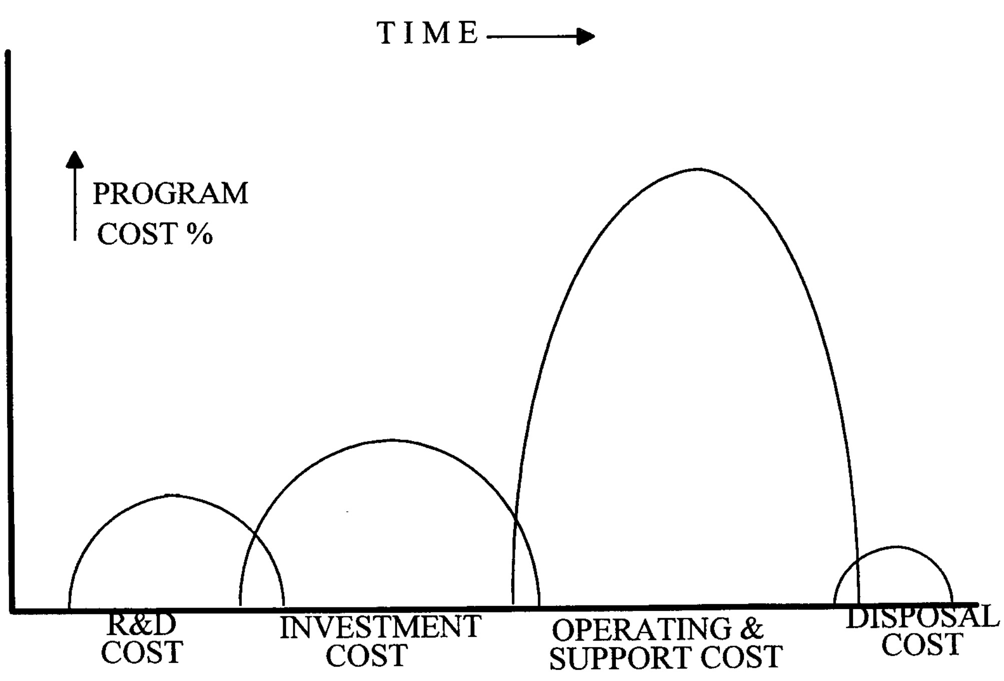


Figure 3. Life-Cycle Cost Components

The Concept Baseline is now approved and the cost/affordability constraints are provided. DEM/VAL further explores the most promising solutions from the Concept Exploration phase, identifying and considering competing designs to take full advantage of the economical benefits of competition.

Milestone II, Development Approval, marks the start of the Engineering and Manufacturing Development (EMD) phase and establishes the baseline low-rate initial production (LRIP) quantities, along with the specific cost, schedule, and performance criteria that must be achieved prior to exiting this phase of the process. The objective of the EMD phase is threefold: first, translate the design approach developed in DEM/VAL into a stable system design; second, validate the manufacturing/production processes; and third, demonstrate that the system produced will satisfy the minimum acceptable performance objectives.[16] These objectives are accomplished by scaling-up the prototype model to full size and ordering a limited quantity to validate production techniques and quality. Several of these limited quantity systems will be used for both operational and interoperability testing in an effort to verify the satisfaction of the minimum acceptable performance criteria.

Milestone III, Production Approval, establishes the production baseline and approves entry into the Production and Deployment phase of the acquisition process. This milestone involves a reassessment of life-cycle costs,

affordability, performance, and threat factors. The Production and Deployment phase focuses on weapon system quality and performance. Full-rate production of the system is achieved by shifting from low-rate production for testing to producing and fielding relatively large quantities, using assembly line methods. The majority of the program funds are expended during this phase along with the implicit obligation of significant operations and maintenance funds in future years to support the fielded systems.[17] One important note, the incorporation of any and all approved improvements to the original design is scheduled for future production lots during this phase. The cost impacts associated with unplanned changes can be enormous.

Milestone IV, Major Modification Approval, provides for determining if major upgrades to a system in production are warranted and also establishes the appropriate baseline if necessary. Phase IV, Operations and Support, is actually a continuation of the Production and Deployment phase. The objectives of this phase are to correct quality and safety problems, ensure the system continues to meet the threat, and identify any shortcomings or deficiencies.[18]

Deficiencies occur when the system can no longer meet the needs of the user due to an improvement in the threat, a change in policy, or technological obsolescence and aging. In an effort to remedy the deficiency, changes in operation, maintenance, or training are generally looked at first. The same rationale used for satisfying the original need is used here. However, once again, if these actions are

insufficient to correct the deficiency, it may become necessary to acquire a system to correct the deficiency. If the current system is still in production, proposed options are prepared along with new baseline data to support a new acquisition strategy. If the current system is out of production, a new MNS will be generated and through the requirements identification process, the decision for a system modification or a new system start will be made.

D. PROGRAM MANAGEMENT

Internal and external management of the acquisition process is as equally complicated as the process itself. Externally, there are a number of agencies that the program office must coordinate with daily. Some of these agencies may ultimately decide the fate of the program including funding availability and performance/cost trade-off considerations. Internally, the program office is typically organized as a matrix organization. Personnel from different functional areas are assigned to the program on a temporary basis. The PM is able to draw on the individual expertise of the personnel to field the system within all of the requirements and constraints. The different functional areas include: the projects division, the configuration management division, the contracts division, the engineering division, the logistics division, the program control division, the manufacturing division, and the test division.

Each of the functional divisions listed above has a certain responsibility in the overall scheme. For the purpose of this thesis, however, the discussion of these divisions will be limited to configuration management, program control, and logistics. The configuration management division is responsible for tracking the various technical baselines and managing the engineering change proposal process. The configuration of a system, as defined in *Acquisition of Defense Systems*, is "its set of descriptive and governing characteristics that can be expressed in both functional and physical terms.[19] This is an important point, since, the configuration of a system helps define a basis of comparing different systems.

Program control is generally responsible for all of the fiscal and budgetary aspects of the program. This responsibility extends to tracking the allocation of funds, contractor costs, and schedule performance and acting as the interface with any outside audit agencies. Tracking the allocation of funds is a very important task. During the execution phase of the budget, funds are expended on different aspects of the program. Fiscal integrity and appropriations integrity, however, must be maintained. That means that we can not spend more money than the program was appropriated, we can not spend money from one appropriations category on costs of another, and we must spend the money prior to the appropriations expiration.

The logistics division ensures that the logistical considerations of the system are given top priority. These

logistical considerations are directly associated with operation and support of the system after it has been deployed. As will be discussed in a later chapter, there are major trade-off decisions between the acquisition cost now and reliability and maintainability issues later. In order to make that trade-off decision, the system must be designed with support in mind early in the acquisition cycle.

E. ACQUISITION STRATEGIES

DoDI 5000.2 states that the primary goal in developing an acquisition strategy is to minimize the time and cost of satisfying an identified, validated need consistent with common sense, sound business practices, and the basic policies established by the DoDD 5000.1. The acquisition strategy can be thought of as the method for acquiring the system and as such, there are several different methods of acquisition available. These methods include: research, development, test, and evaluation (RDT&E), non-developmental item (NDI), service life extension (SLEP), and pre-planned product improvement (P^3I). The method chosen has a large impact on the cost, schedule, performance, and supportability of the system.[20]

The RDT&E approach to acquiring the system is probably the most costly and time consuming. This is the approach depicted in the acquisition process of Figure 2. NDI is probably one of the most cost-effective acquisition methods

available. The basis of this method concerns acquiring an existing weapon system, sometimes with minor modifications, and adapting it for military use. Systems that would fall into this category include commercial-of-the-shelf (COTS) items that are purchased through commercial channels. This approach saves much of the costs associated with developing the item from the ground up and the system may also be fielded in a shorter amount of time.

The service life extension program involves refurbishing an existing system to prolong its useful life beyond the end of its life-cycle. Frequently included in this method of acquisition is an upgrade program which allows the current system to take on some new capabilities. This is the basis of one of the acquisition methods used in our case study program.

For the recapitalization of the HMLAs, non-material alternatives have been analyzed and evaluated by the Studies and Analysis Branch of the Marine Corps Combat Development Center (MCCDC). The conclusion fostered a hardware solution: acquire an interim weapon system that will meet the performance requirements at the lowest possible cost. Alternatives were developed on the basis of obtaining the most performance at the lowest cost. These alternatives are compared to one another and the system with the best overall performance-cost trade off is usually chosen. This upgrade program has one additional dimension that must be noted. By modifying one aircraft with components of the other aircraft, the proverbial "killing two birds with one stone"

may be accomplished. This method may allow for an increase in the future flexibility of the attack helicopter while solving most of the problems of the aging light assault helicopter, and at the same time , causing a real cost savings. This savings would be associated with a common component base for the operations and support of the aircraft after deployment.

On the surface, this approach may seem cost effective and prudent, but are the alternatives a better choice? That is the question which the PM faces. The remainder of this thesis will discuss and explore how to aid the PM in making this choice.

III. COST-ESTIMATION AND FORECASTING

A. COST OVERVIEW

As discussed in the previous chapter, the major constraint in the acquisition of a system is the funding. If unlimited funds were available, the procurement decision-making process would be quite simple; decide which system meets the performance requirements of the user, then merely procure as many as necessary. Funding, however, is far from unlimited and the competition for these funds is very intense. So intense, that in recent years, competing programs have been evaluated on the basis of "the most bang for the buck." Funds are appropriated by Congress for the research and development (RDT&E), procurement (APN), and operations and maintenance (O&M) of the system being acquired. Appropriations are permission to obligate the Treasury to pay for goods or services.

Requests for funding are submitted in the form of a budget request. Budgets are used to track the funds and ensure their effective and efficient use. Ideally, budgets are based on the required costs necessary to satisfy some program requirements.[21] And, in order to remain within the budget, the required costs must be aggressively managed and kept to the absolute minimum. But what are these required costs and how are they identified? Cost-estimation techniques are used to develop and identify the required

costs associated with a program and is the basis upon which budgets are formulated and revised.[22] As defined by the Air Force Systems Command, cost-estimation is:

> The process of projecting financial requirements to accomplish a specified objective. It includes selecting estimating structures; collecting, evaluating, and applying data; choosing and applying estimating methods; and providing full documentation.[23]

With that said, it can also be stated that costs become the dominant driving force in the decision-making process for the acquisition of systems. Alternatives are evaluated on the basis of not only performance, but also costs. It becomes clear that cost-estimates must accurately reflect the financial requirements of the program in question. A program's viability can be seriously impaired if measured against a less than competent cost-estimate.[24]

A cost-estimate has several characteristics associated with it. There is completeness, reasonableness, consistency, and good documentation. Completeness requires that all relevant costs must be included in the estimate. This means all costs incurred during the useful life of the acquired system must be used. These costs are known as the life-cycle costs of the system and will be discussed in detail in the next chapter of this thesis. Reasonableness pertains to the cost-estimating methodology and its suitability for the program element being estimated. Consistency relates the assumptions made in the cost-estimate concerning the acquisition strategy, and

documentation deals with clear, concise supporting statements used in the estimate.

Cost-estimates are not restricted to the outset of the program. In fact, it is important to note that the cost-estimating process occurs at a specific point in the life-cycle of the system and is therefore only as accurate as the information available at that point in time.[25] Keeping this in mind, it becomes evident that cost-estimates can and do occur throughout the life-cycle of the program and have several different functions. One of the most important functions is to provide key cost information early on in the acquisition process. At this point in a program's life-cycle, it is crucial to develop as accurate a cost-estimate as possible, because many complex and important decisions are made, based on this estimate, that affect the program throughout its life-cycle.[26] The complex and important decisions concern choices among alternative systems. DoDI 5000.2 states, "Cost estimates shall be comprehensive in character, identifying all elements of additional cost that would be entailed by a decision to proceed with development, production, and operation of the system."[27] This is particularly true for the early estimates.

As defined by DoDD 5000.4, cost estimation is an analysis and presentation of the future costs of an object or service, based on prior cost history of the same or similar system.[28] In an effort to achieve accurate decision-making models, not only must the most relevant

costs be used, but the most accurate method of estimating these costs must also be used. Cost-estimating techniques will be addressed in detail in the following sections. The current popular methods used include analogy, parametric or statistical, engineering, and extrapolation from actuals. These methods are presented in respect to a hierarchy ranging from gross estimates to detailed estimates. It is important to understand that a certain method may be more appropriate during one or more phases of the acquisition program. Figure 4 illustrates this relationship.[29]

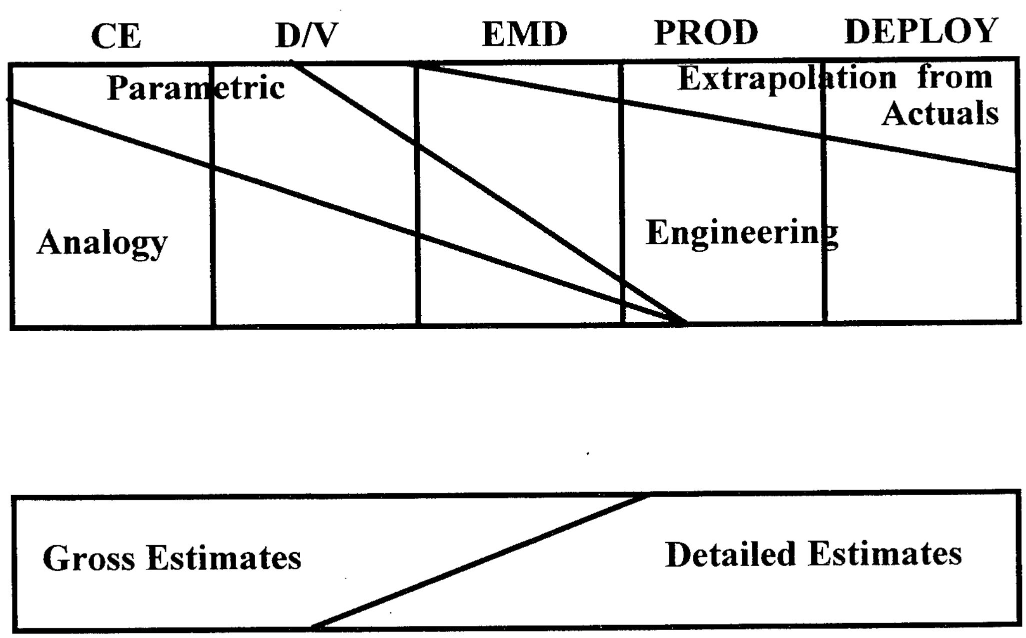


Figure 4. Cost-estimating Methods and Acquisition Phase

The analogy method uses elements that are based on a similar system. The costs associated with that system form the basis of the costs of the new system. Parametric models use elements of a data base to form the cost-estimation. Engineering models are the most expensive type and entail reducing the system to its components and each element is costed out. The last model used, extrapolation, is very accurate since all of the data are derived from a previously produced version of the system, usually a prototype or other test article. A major drawback to this model would be the timing of when the estimates could be applied. Since the data are based on prior manufactured system, the system must have already been produced to obtain the cost data. However, this could only occur late in the acquisition cycle.

It is important to note that these methods are not mutually exclusive. Analysts are encouraged to employ alternative cost-estimating methods concurrently to expose hidden factors such as design and schedule risk areas and to reinforce the estimates derived.[30] Remember, the object is to provide the most accurate cost-estimates possible within the constraints of time, data, and the methodology.

B. ANALOGY METHOD

The analogy method of cost-estimation is based on a comparison of one system with one or many like systems. Specifically, this method compares a new system with one or

more existing systems/subsystems for which there is reliable cost and technical data.[31] The cost analyst makes a subjective evaluation on the similarities and differences of the new system and some existing system or systems. A relationship between the new system and the old system is assumed based on this evaluation. To make the relationship as meaningful as possible, engineers and technicians normally provide a technical evaluation of the systems. Based on this technical evaluation which explicitly adjusts for differences in technological, operational, and/or logistical variables between the two systems, the cost analyst can make a more accurate assessment of the cost impact.[32] In the end however, the resulting estimate is still based on subjective evaluations by both the technical staff members and cost analysts.

The subjective nature of these evaluations is the source of some uncertainty in this cost-estimating method. Once again, the key here is to develop an accurate cost relationship based upon the technical differences between the new system and some similar existing system. For the most part, these differences are qualitative at best. However, if for one moment we can assume that the technical differences can be captured quantitatively and objectively by the technical staff, thereby reducing the technical uncertainty of the relationship, the cost analysts must still determine the cost impact. These cost impacts are still highly subjective and their results on the estimate can cause a level of total uncertainty that is quite large.

Due to the aforementioned restrictions, the analogy method is most suitable early in the life-cycle of the program. Generally, this method is used during the Concept Exploration and Demonstration/Validation phases. This is usually a time when actual cost data for the system in question is scarce or not available and may reflect uncertainty associated with the preliminary system design definition.

C. PARAMETRIC METHOD

The parametric method also compares one system to another system. However, this method differs from the analogy method in that statistical inferences are made when comparing the new system to multiple like systems.[33] The comparison is made possible by a data base of like elements which shows a relationship between a particular cost and one or more cost drivers. An estimate based on some representative system performance parameter or design characteristic is then produced by employing least squares regression techniques to derive a cost-estimating relationship for the performance parameter chosen.

Two critical assumptions are made when using this method. First, there is a relationship between the performance parameter selected such as speed, weight, thrust (independent variables) and the system cost (dependent variable).[34] Second, the requirement for a good data base is being satisfied. The data base used must reflect "like

technology" to the system of interest and contain the latest most up to date data available.

The parametric method is also useful early in the program life-cycle. It has been generally used when a detailed design specification is not available, but a performance specification is, along with a data base of like systems.[35] Due to the reliance on performance specifications and cost-estimating relationships, it is very simple to adapt this method for changes in the design, performance, or programmatic characteristics. However, this simplicity does not come without its own cost. If the assumptions outlined above are not satisfied, erroneous cost-estimates may result.

D. ENGINEERING METHOD

The engineering method, also known as the "bottoms-up" method, is generally the most detailed and most expensive method to use.[36] This method uses known and/or estimated costs of separate lower level items of the work breakdown structure (WBS) and sums them to arrive at an overall system cost. This summation includes an adjustment for non-estimated elements such as quality assurance and system engineering to achieve the most accurate results possible. Work breakdown structure results from an analysis of system requirements and captures all products and services which comprise the entire work effort. In other words, the analyst begins at the lowest level of identifiable work

effort with engineering drawings and specifications, identifying each labor task and materials necessary to accomplish the work.[37] The adjustment is made by applying a multiplicative factoring to each of the separate lower level estimates.

It must be understood that this method not only breaks the cost down to the lowest level possible, but also uses different methods of estimating these separate costs. For example, the analogy method, parametric method, or extrapolation method may be used on an item to achieve the most accurate estimate possible for that item. As with the other methods of estimation, the engineering method also has its inherent uncertainty. This is due to the compounding effect of summing the adjustments made on the lower level items. If the individual adjustments are erroneous, rather large errors can be produced once the adjustments are summed.

E. EXTRAPOLATION METHOD

The extrapolation method uses updated cost-estimates based on actual costs of a prior production of the same system. The technique involves the use of previous cost data gathered on earlier units of the same system.[38] These earlier units may be prototype models used for developmental test and evaluation or units produced during low rate initial production (LRIP). Low rate initial production provides production-configured units for operational test

and evaluation, establishes an initial production base for the system, and permits an orderly increase in the production rate leading to full rate production.

This method of estimation is arguably the most accurate when the actual cost data are available. This is because the earlier system is more like the new system than any other historic system. But, the cost data generated from the earlier system is generally only available late in the acquisition cycle. It becomes obvious then, that the further along the system is in the acquisition process, the more accurate the cost-estimation.

Although highly accurate, this method still has some level of uncertainty associated with its use. As with the analogy method, this method is also based on the technical evaluations of differences between the new system and some other existing system. Even though this method uses a prior version of the existing system, the systems in question may not be totally the same. Since by definition, the new production system may contain technical upgrades that either were not available for the prototype, or came about as a direct result of some shortfall identified during testing of the prototype. Also, prototypes are generally hand-produced by high-level engineers and technicians. Production units will be made on production floors by semi-skilled workers in much larger quantities with reduced costs. These differences must be factored into the cost-estimate to obtain the most accurate estimate possible.

F. FORECASTING TECHNIQUES

The definition of forecast, according to *Random House*, is to form an opinion beforehand; to predict. Although there are many different approaches to attacking a forecasting problem, there are generally only three bases for forecasting the future.[39] "Things will remain the same" is always a possibility in forecasting future events. Analysts use the current trend as a template for future events. The analysis of past history takes the first technique one step further. This type of forecasting technique is known as time series analysis. The most popular method, however, is to analyze the causative factors at work on the variable to be forecasted. A relationships between the variable and the causative factors are first developed, then a determination is made as to the importance of each relationship. Forecasts of this type are known as regression analysis.

1. It-Is-Going-To-Be-Just-Like-Now

This method of forecasting is perhaps the most basic, but not necessarily the most useless.[40] The assumption is that the factors affecting the forecast will remain the same. This method generally has some merit when the period of the forecast is relatively short. For that reason, this method is normally employed for short-term decision-making.

As the forecast period becomes longer, the probability of the assumption holding true becomes smaller.

2. Time-Series Analysis

Time-series analysis is based on the assumption that the variables to be forecasted have the characteristic of taking on a particular value at a particular time. A relationship or pattern between the variable value and a time index is identified and used to forecast the variable value at some future time. Two of the most popular approaches to time-series analysis are the Classical Decomposition Method and the Box-Jenkins Method. In the Classical Decomposition Method, the patterns are broken down into smaller subpatterns which represent the different factors that influence the value of the series.[41]

The Box-Jenkins Method is based on dividing the forecasting problem into three distinct stages. First, a forecasting model most relevant to the problem is developed. Then, the model is "fitted" to the available historical data and evaluated for suitability. If the model is found to be lacking, the process returns to step one and another model is developed. Finally, once a suitable model has been identified, the forecast is developed for some future time.

3. Regression Analysis

Regression is a technique of quantifying relationships between variables.[42] The causative factors affecting the variables are analyzed and a relationship is developed. The relationship is usually between a dependent variable, which is the one being forecasted, and one or more independent variables, also called explanatory variables. The forecast is actually based on this relationship and any expected changes in the environment. Once these relationships have been developed, a determination on their significance is made using some type of mathematical technique. Those relationships found to be insignificant are discarded and a forecast is made on the relationship of the remaining variables. Regression analysis is probably one of, if not the most, popular method of forecasting.

4. Learning Curve Theory

Learning curve theory is not derived from some theoretical construct, but rather is actually based on consistent observations of production cost data in certain industries.[43] The phenomenon is, in reality, a special case of regression analysis and is acknowledged as a significant instrument in estimating costs. Learning curve theory is not in and of itself a cost-estimating method, but instead, it is a technique for predicting how certain causative factors affect the variable to be predicted. It is more of

a tool which allows the aforementioned methods to be more accurate. Basically, it works like this: a worker learns as he or she performs a task; and as a worker performs a task over and over again, he or she becomes more efficient at that task resulting in a reduction in the amount of time it takes to perform that task. There are many factors involved in this efficiency increase. However, those most commonly mentioned are job familiarization of workers as a result of repetition, general improvement in shop organization/ coordination, development of more efficient parts-supply systems, and improvement in overall management.[44]

It is important to note that the factors above are all related to labor costs and production. In fact, learning curve theory's greatest utility is in estimating costs associated with labor and production schedules. More specifically, when the cumulative quantity produced doubles, the cost per unit decreases by some fixed percentage. That fixed percentage can be calculated and applied to other cost-estimating methods to provide a more accurate estimate.

As with the cost-estimation models previously discussed, learning curve theory also has its limitations. As stated above, learning curve is normally applied to the cost of direct labor and production. But with the advent of computer aided design (CAD) and computer aided manufacturing (CAM) techniques, less direct labor is necessary to produce the same or even higher outputs. As automation continues to increase in the workplace, the effectiveness of learning curve will be reduced.

5. Simulation

In the recent past, the use of simulation in the field of management has been spreading swiftly. Simulation is a forecasting technique based on a representation of the real world through a mathematical model of a system or process as it moves through time, encountering random events.[45] Usually the mathematical model is in the form of some type of spreadsheet application. Model building is a difficult task for, the model must capture the most important aspects of the real world situation. These aspects are reduced to some type of mathematical relationship, thus simplifying them and allowing them to more easily managed. As alluded to earlier, the proliferation of the personal computer has caused a virtual information explosion. Applications and techniques that were once reserved for large mainframes can now be handled with ease by most of today's personal computers.

The forecasting in simulation is derived from the model moving through time and encountering random events along the way. It is the movement and randomness that allows the simulation to mirror a real-world situation. Monte Carlo simulation is among the most popular methods of simulating real world events. Many add-in software programs offer the capability to run a Monte Carlo simulation on an existing spreadsheet model. Simulation will be discussed more fully in Chapter V.

G. NAVAIR ESTIMATES

Now that the relative strengths and weaknesses of the different cost-estimation methods have been identified and the various forecasting techniques have been described, the actual cost-estimation techniques used in this case can be introduced. First of all, the cost-estimates included in this acquisition strategy are from multiple sources and therefore an inherent risk of comparing "apples to oranges" does exist. This drawback is due to the data being gathered from different sources and not because of the different methodologies used. Second, many of the estimates are presented as a range of costs. These ranges reflect a level of uncertainty in the estimate that is normally part of early stage estimates. The uncertainty is a result of cost uncertainty and does not reflect any technical uncertainty.

There are several relevant assumptions related to the cost-estimates of this acquisition strategy. The following assumptions hold true for the recurring costs of the systems. These recurring costs are limited to the unit cost of the system. The assumptions used for the remaining costs of ownership will be discussed in the next chapter as part of the life-cycle cost discussion.

1. AH-4BW:

- The engines and all of the avionics is government furnished equipment (GFE).

- 180 total aircraft are modified to 4BW configuration.

- 24 aircraft are modified per year and common 4BN components are also in production concurrently.

- All costs are in FY94 dollars.

- All work is performed at Bell Helicopter using Bell composite rates and includes a 15% profit.

- The costs are derived parametrically using Bell Helicopter analyses and validated by NAVAIR.

2. UH-4BN:

- The engines and all of the avionics is government furnished equipment (GFE).

- 100 total aircraft are modified to 4BN configuration.

- 12 aircraft are modified per year and common 4BW components are also in production concurrently.

- All costs are in FY94 dollars.

- All work is performed at Bell Helicopter using Bell composite rates and includes a 15% profit.

- The costs are derived parametrically using Bell Helicopter analyses and validated by NAVAIR.

3. RAH-66(M)/AH-64D(M):

- The cost-estimates are based on additions to Army ROMs.

- Technical baselines and aircraft configurations are not clearly defined and do not allow for an engineering assessment of design or marinization efforts to be conducted.

- All costs are in FY94 dollars.

4. CH-60(M) (H & L Baselines):

- The costs are derived using top-level engineering assessment of the baseline aircraft with NAVAIR data and methods.

- The unit costs are also based, in part, on a future Army buy of UH-60L.

- All costs are in FY94 dollars.

The distinction of comparing apples to oranges is more readily apparent now that the assumptions have been identified. We will return to these assumptions in the chapter on cost analysis and attempt to ascertain how a change in some of these assumptions can impact the acquisition strategy.

IV. LIFE-CYCLE COSTS

A. OVERVIEW

The cost of acquiring a major weapon system is not limited to the mere purchase price of that system. There are other costs associated with that system's ownership. For example, the ownership cost may also include the cost of purchasing spare parts, fulfilling training and manpower requirements, and disposal/retirement of that system at the end of its useful life. These additional costs are very relevant and must be included in the overall estimate of the system cost. As previously stated, in order to obtain a good cost-estimate of a system, the characteristic of completeness must be satisfied. Therefore, all costs associated with the acquisition and ownership of the system are relevant and must be included in the overall cost-estimate of that system. As defined in the Integrated Logistics Support (ILS) Guide, "Life-cycle cost (LCC) is the total cost to the Government of the acquisition and ownership of the system over its full life. It includes the cost of development, acquisition, operation, support, and where applicable, disposal."[46]

In the preceding chapter, methods for estimating the costs associated with the acquisition of major systems were introduced and discussed. These techniques allow the cost analyst to make the most accurate cost estimates possible for cost significant decision-making purposes. This means

that for decisions involving the comparison of relative costs of design and acquisition alternatives under consideration, a comprehensive cost structure with accurate estimates must be used. This is a very important distinction given that most, if not all of the decisions made during the acquisition process have some type of cost implication. This chapter will attempt to identify which costs are most relevant and in need of estimation. Furthermore, the major assumptions necessary in estimating these costs and their implications will be explored.

There are several different types of costs used in the acquisition process and in order to compare the costs of alternatives, a common frame of reference must be identified. There is a hierarchy of system costs ranging from the procurement cost of a basic unit through an overall cost to the government or life-cycle cost. Figure 5 depicts this system cost hierarchy.

Design to unit production cost (DTUPC) is the procurement cost of the basic unit less spare parts but includes all recurring production costs. Flyaway cost is the DTUPC plus any non-recurring production or capitalization costs. Weapon system cost is flyaway cost plus the cost of any item required to make the system deployable. However, weapon system cost does not include the cost of spares. Procurement cost is the most frequently used cost and consists of weapon system cost plus the cost of initial spares. The initial spares cover the first year of deployment and are funded through the procurement

appropriation. Program acquisition cost is the procurement cost plus research, development, test, and evaluation costs and any military construction (MILCON) costs related to the system. Finally, life-cycle cost is the program acquisition cost plus operating and support (O&S) cost and disposal cost. Operating and support costs include any related cost of operations and maintenance (O&M) and manpower requirements (MILPERS) for that system. The life-cycle cost represents the total cost to the government for the ownership of that weapon system.

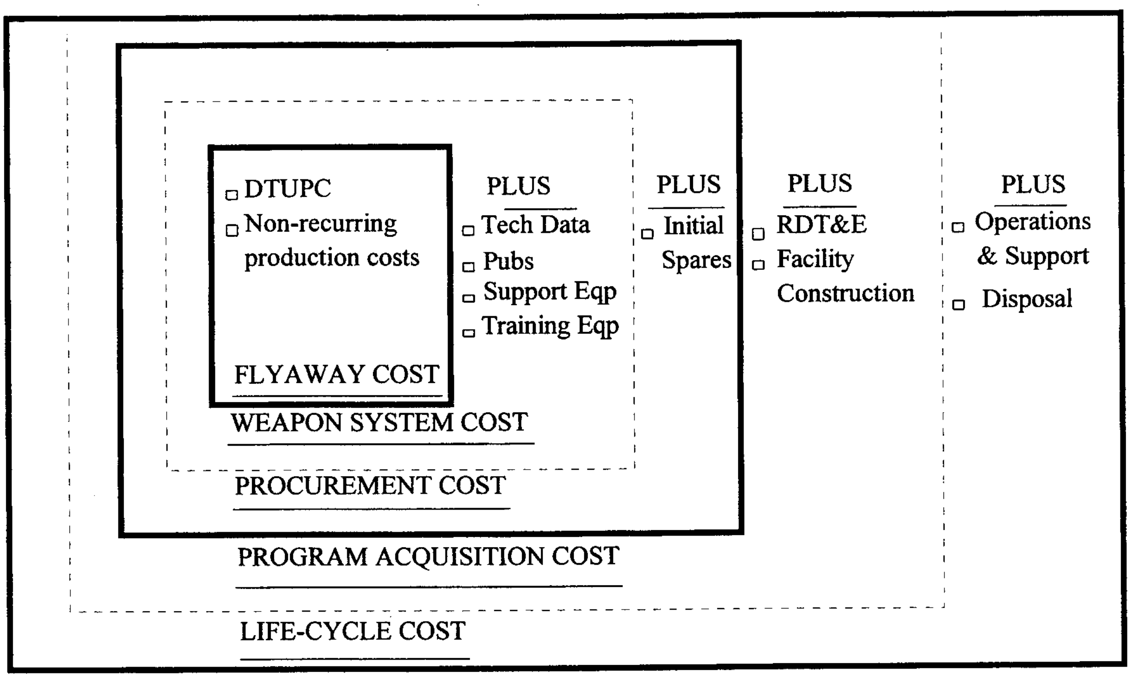


Figure 5. Life-Cycle Cost Composition

As discussed previously, the accuracy of a cost-estimate is based in part on the data available at the

time of the estimate. For this reason, several cost-estimates may be performed throughout the acquisition program. In fact, a cost-estimate must be developed for each milestone review. However, estimating the cost of a system prior to its development and production is arguably one of the most important estimates and usually has the least amount of available data. Once again, production costs are not the only relevant costs used to base a procurement decision upon. Elements such as cost of spare and repair parts throughout the systems useful life, manpower costs associated with operating and maintaining the system, and training cost associated with providing training for effective operation of the system are also included. These are costs that are incurred after the system is deployed but, nevertheless must be estimated and included in the initial cost-estimate.

It is obvious that accurate cost-estimates are necessary to permit the comparison of acquisition alternatives. But, how do the decisions made now impact the future costs of the system? And more specifically, what decisions should be made now to decrease the future costs of the system? In order to capture and fully appreciate the future costs and the impact of current decisions on those costs, an analysis of the life-cycle cost is used. First of all, the system life-cycle is divided into four main categories of cost: Research and development (R&D), production, operating and support (O&S), and when necessary, disposal. The ILS Guide identifies two goals of life-cycle

cost analysis: (1) To identify the total cost of alternative means of countering a threat, achieving production schedules, and attaining system readiness and performance objectives; and (2) estimate the cost impact of the various design and support options.[47] These various design and support options are based partly on assumptions about how the system will be operated once it is deployed. It is these assumptions which impact the design and logistics choices at the outset of the program. Cost drivers identify the assumptions made and relate those assumptions to costs.

This concept of life-cycle cost analysis is most effective in the early phases of the acquisition process. It has been estimated that on the average, roughly 85% of the systems life-cycle costs have been committed by design and logistics choices prior to Milestone II.[48] It is important to understand that this represents funds committed, not funds actually expended. Figure 6 depicts this relationship. It is also important to note that once these design and logistics choices have been made, it is always more costly to modify them. It would behoove the program manager to obtain the most accurate life-cycle cost estimate possible at the outset of the program to preclude cost increases later in the system's life-cycle.

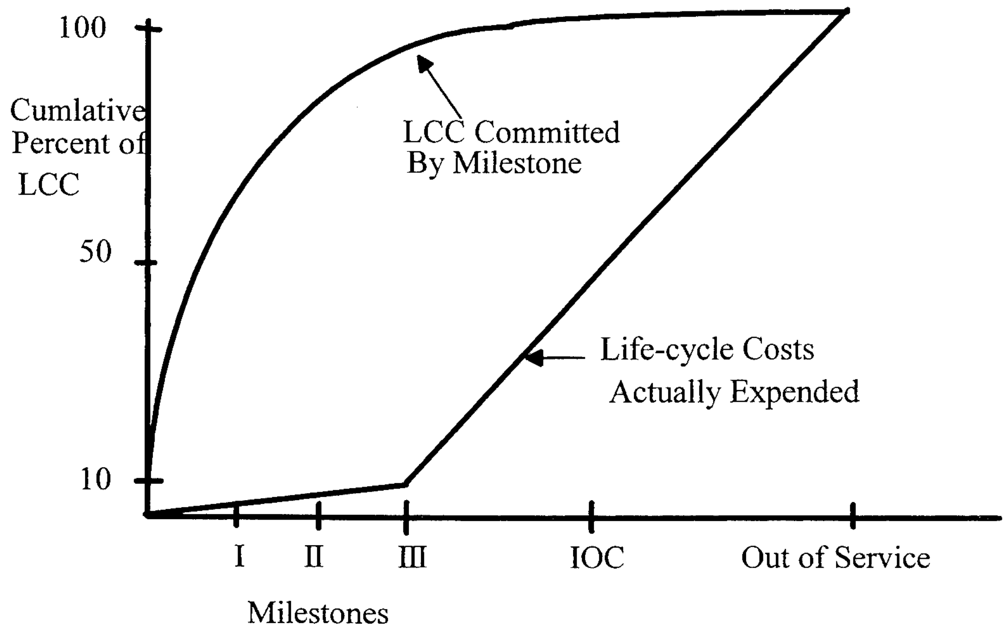


Figure 6. Typical System Life-cycle Cost Commitment

From a life-cycle cost perspective, systems go through sequential cost stages. As discussed above, the major components of the life-cycle are research and development costs (R&D), investment or production costs, operations and support costs (O&S), and disposal costs. These components are further subdivided into lower levels of elements to better manage and track the costs. As discussed in chapter 1, the production and O&S costs are by far the most expensive costs incurred throughout the system's life-cycle. The systems we are acquiring are designed to meet very high performance objectives resulting in an increase in complexity and cost. However, as the systems acquired become increasingly more complex, they become more difficult

and expensive to maintain. Currently, as described in an earlier chapter, the operating and support costs related to operating and maintaining those systems has risen to an average of 60% of the total life-cycle cost. This relationship is shown in Figure 7.[49]

A more detailed description of each of these costs follows. However, it seems intuitively obvious that the life-cycle costs with the most impact are the largest costs. That is, the cost with the most risk of variance from the baseline cost-estimates are the largest life-cycle cost elements. From figure below, those costs would seem to be production and O&S.

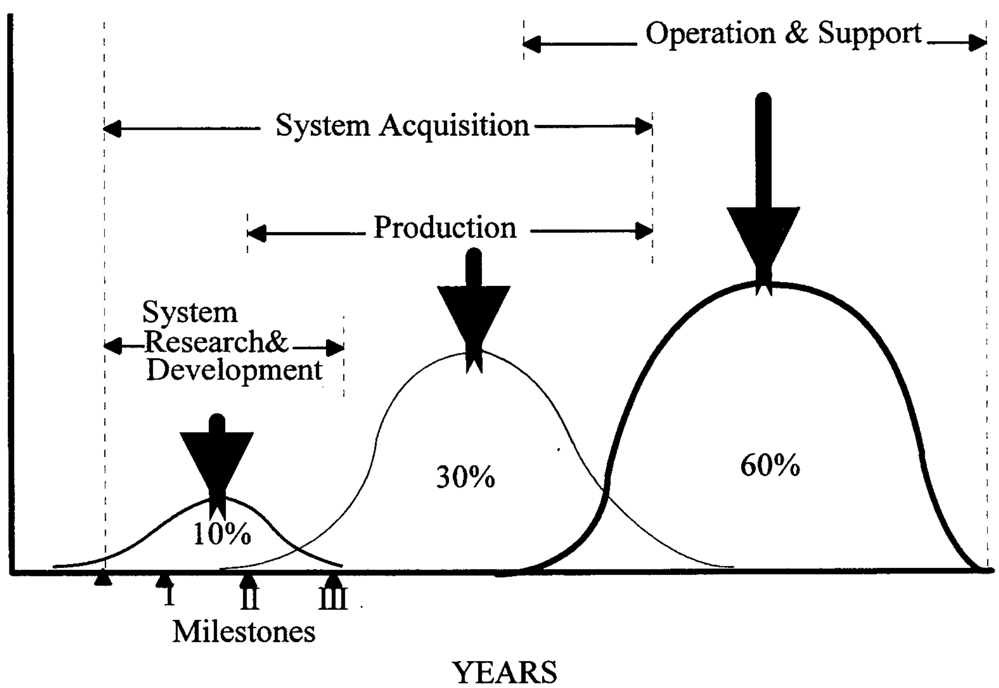


Figure 7. Typical System Life-Cycle Cost Distribution

B. RESEARCH AND DEVELOPMENT COSTS

The costs normally associated with research and development also typically include the costs of test and evaluation. RDT&E costs are normally most prevalent in the earlier milestones and phases of the acquisition process. These costs typically account for roughly ten percent of the overall life-cycle cost. Under this process, the concept of research takes on many facets. Some research is aimed at studying competing concepts and their ramifications, while other research is strictly examining technical issues associated with the design of the system.

There are many formal studies undertaken prior to the procurement of a system. Concept studies are used to determine if the mission need is valid and identify a minimum set of alternative concepts to possibly satisfy that need. Concept exploration phase explores various material alternatives along with studying the impact the proposed system will have on the surrounding environment.

It is important to note the source of research and development funding. Chapter 2 discussed the funding requirements for major system acquisitions and the "pot of money" concept. Currently, all research and development costs are covered under the Research, Development, Test, and Evaluation (RDT&E) appropriation. These costs include concept studies, technical research, and design.

C. ACQUISITION COSTS

Acquisition costs include the cost of procurement and the cost of facilities. Sometimes called production cost, procurement costs consist of the cost of a basic unit plus capitalization costs, support equipment, publications, and the cost of any system-peculiar training equipment. These costs are funded through a procurement appropriation and include the cost of initial spares. The major cost-drivers related to procurement costs include selected design characteristics, performance requirements, and schedule/production factors.

Facilities costs represent the costs of purchasing and furnishing the facilities necessary for deployment of the system. These cost are funded by the Military Construction (MILCON) appropriation. Costs associated with facilities usually take on an added dimension of risk. The funding involved is historically characterized by long lead times. These lead times can range from five to seven years in length, which necessitates the appropriation of these funds well in advance of production.

D. OPERATING AND SUPPORT COST

As previously discussed, operating and support costs currently account for approximately 60% of the life-cycle costs of the system. This percentage represents an average cost of many different programs and is based on about 60% of

the total DoD budget is dedicated to the support of operational systems. Nevertheless, this still represents a great concern.[49] Operating and support cost is defined as the costs necessary to operate and support the system once it has been deployed. Typically, these costs include trained manpower, operating consumables, maintenance consumables, support equipment, technical manuals, training, and spares. A full O&S cost element breakdown structure is included in Appendix C.

Funding of the operating and support costs is achieved through both the Operations and Maintenance (O&M) appropriation and the Military Personnel (MILPERS) appropriation. The cost of spare parts and manpower represent two of the largest operating and support costs. As such, the assumptions associated with these two cost elements should be cause for concern. The assumptions are related to reliability and maintainability issues of the system. From the assumptions, cost drivers are developed to assist in estimating these costs for some future time period. The cost-estimates are then consolidated to form the total life-cycle cost estimate which serves as the baseline cost-estimate for that system and is compared to the total life-cycle cost estimate of competing systems. The importance of these assumptions becomes very obvious. If the cost drivers are based upon incorrect assumptions, then the chances that the cost drivers and the associated cost-estimates may also be incorrect, are increased. This

can result in funding shortfalls in the middle of the system's life-cycle.

E. DISPOSAL COST

Disposal costs include any and all considerations necessary to retire a system once it has reached the end of its useful life. Retirement is inevitable and though the costs associated with it are small relative to the other costs of the system, theses costs are on the rise. Current and emerging environmental protection laws have increased the costs of disposal over the last few years. That trend is likely to continue into the future. Therefore, cost of disposal should nevertheless be incorporated into the overall system cost when disposal or retirement is necessary.

F. RELATIONSHIP BETWEEN LIFE-CYCLE COST AND SYSTEM READINESS

The issue of affordability not only applies to the procurement of the system (system can be bought at an affordable price) but also applies to the operation and supportability of that system at an affordable price. The LCC estimates must demonstrate whether a system meets affordability goals; i.e., that it can be procured, operated and supported efficiently and effectively within the programmed and budgeted resources in the years of required

operation.[51] To accomplish this, relevant costs associated with the operation and support of the fielded system must be part of the overall cost estimate. As stated in the prior paragraphs, 85 percent of the system's life-cycle cost has been committed by design and logistics choices made prior to Milestone II. It becomes intuitively obvious that the use of life-cycle costs in the early phases of the acquisition process would be the most effective. Experience has shown that the most cost-effective approach to minimizing increases in operations and support costs is to design the systems with support requirements in mind. The current DoD guidelines require the acquisition of systems which meet performance and readiness objectives at an affordable life-cycle cost.[52]

Clearly, the decisions with the greatest chance of affecting life-cycle costs and identifying savings are those decisions impacting acquisition and operating and support costs undertaken during the pre-concept, Concept Exploration, and Demonstration/Validation phases.[53] After the Demonstration/Validation phase, it becomes increasingly more difficult and expensive to change a design element to accommodate cost savings in the future. This undoubtedly forces a trade-off between performance and readiness objectives or, more specifically, between acquisition costs and O&S costs. This relationship is best described graphically as depicted in Figure 8.[54] It can be seen that generally, the more the cost of acquiring (procuring) the system, the less the associated cost of operating and

supporting that system. The rationale behind this phenomenon is simple: The better the design of a system, the fewer maintainability and reliability issues. This, of course, equates to the more money spent on that top of the line system now, the less money required to be spent later for the operation and support of that system.

Life-cycle cost analysis assists in dealing with this trade-off issue by evaluating the cost implications of various design and logistic support alternatives.[53] Early in the acquisition process, the life-cycle cost analysis focuses on the design cost-drivers in an effort to quantify the costs associated with design alternatives which provide the required level of performance. The analysis, however, goes one step deeper. The supportability and readiness objectives are also focused on at this point, along with their cost implications. The cost of ownership is then evaluated on the basis of the acquisition cost-drivers and the readiness cost-drivers.

G. LIFE-CYCLE COST ASSUMPTIONS OF H-1 ACQUISITION

The life-cycle cost assumptions can be found in Appendix D for both the AH-4BW and the UH-4BN. These assumptions form the baseline cost-estimate in this program. The cost-drivers associated with each of the more relevant assumptions will be discussed in the next chapter.

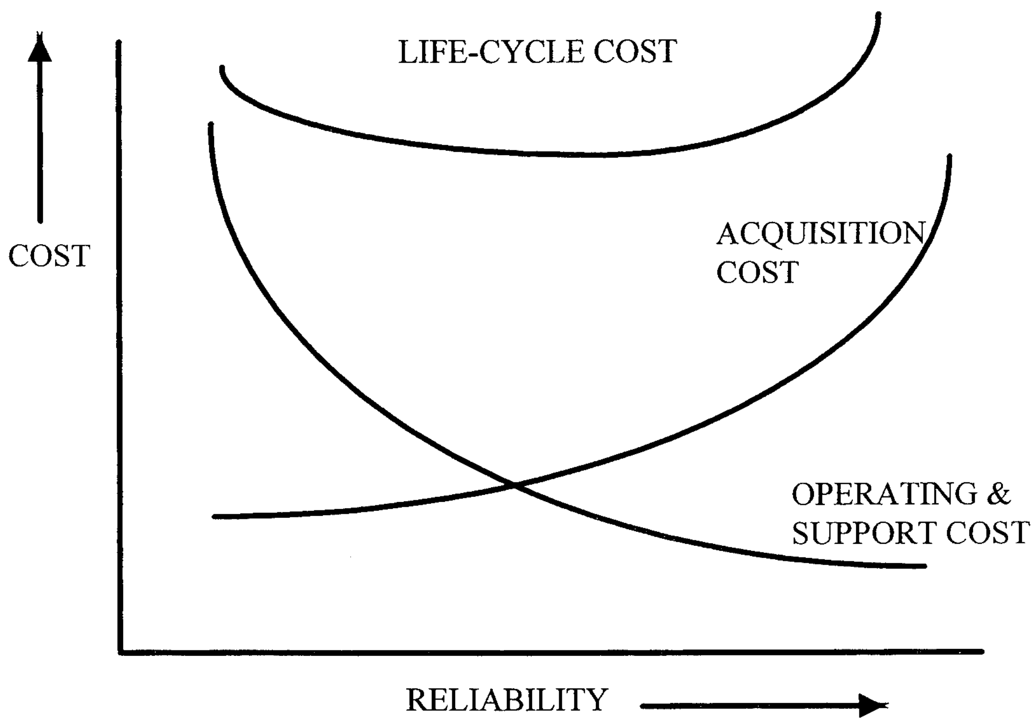


Figure 8. Life-Cycle Cost and Reliability Trade-Off

V. COST ANALYSIS

A. OVERVIEW

Chapter III of this thesis discussed the cost-estimation techniques currently employed by NAVAIR and DoD. Decision-makers must use the cost-estimates developed by the analyst to support most, if not all, of the decisions in the acquisition cycle. These cost-estimates are based on assumptions about the predicted operation of the system being acquired. As explained previously, if the underlying assumptions are flawed, then most likely the cost-estimate will also be flawed. In predicting the future operation of these systems, planners' and cost analysts' assumptions are based on forecasted factors that are often treated as if they were known with certainty. For example, in our case study program, one of the operations and support cost elements, component repair, is based on the assumption that the fatigue life of the components is 10,000 hours of operation. This represents an average number of hours and is treated as a deterministic value when used to generate the cost-estimate relationship and the subsequent cost-estimate. Suppose a more realistic value to use is 8,000 hours, which is based on a probabilistic forecast and reflects the most likely value over a specific length of time? What would be the impact of this revised assumption on the overall O&S costs for the entire life-cycle of the system?

Treating these assumption factors as deterministic may be an acceptable practice for relatively short-term commitments. In fact, when coupled with adjustments based on the experience of that planner or analyst, the method described above may be preferred for short-term decisions. However, as the overall period forecasted becomes longer, the element of uncertainty becomes larger, increasing the potential for more variations in the cost-drivers. Therefore, decisions with longer-term impacts are generally riskier than those of the shorter-term variety.

Chapter IV discussed the concept of life-cycle cost and its impact on evaluating the acquisition of competing systems. It was also discussed that the operating and support costs now comprise approximately 60% of the LCC for the system. In our case study program, the aircraft being acquired can expect to be in operation until the year 2020. The twenty or so years of operation has a corresponding long-term O&S cost that must be estimated prior to the acquisition strategy being implemented. This is to say that accurate cost-estimates based on accurate forecasting assumptions and techniques must be applied early enough in the acquisition cycle to assist the PM with the decision between these competing strategies.

As previously stated, these acquisition decisions are based mainly on cost and effectiveness. For the purpose of this analysis, the alternatives are compared on the basis of equal-effectiveness. Although some alternative systems may posses higher capabilities than others, alternative

selection is predicated on the system meeting some preset performance requirement or threshold. Once the effectiveness threshold has been met, alternative systems can then be compared on the basis of forecasted operating and support costs. If the threshold is not met, the system is removed from consideration. The thresholds represent the minimum acceptable performance that could be tolerated in the system in question and have been developed by NAVAIR as part of their effectiveness analysis for this program.

Cost inputs to the analysis should be validated to identify the weaknesses or "soft areas" in the cost-estimate.[54] Weaknesses include poor cost-estimating relationships (CERs) used in the inputs, treatment of cost-estimates as deterministic inputs into the analysis, and cost inputs that do not reflect the entire range of relevant costs. It is obvious that the last weakness listed will render the analysis incomplete and the first weakness will cause inaccuracies in the input data. However, the tendency to treat the resulting cost-estimate as a deterministic input to the analysis can also cause very large amount of errors.

The purpose of this analysis is to offer the Program Manager decision support tools which focus on analytical techniques for decision-making. The methods described are quantitative in nature but may also be used to derive qualitative results. The scope of the analysis is limited to the operations and support costs associated with the recapitalization of the HMLA assets. Research and

development costs, acquisition costs, and disposal costs are treated as known quantities and held constant throughout the analysis. These costs could be included in the analysis to obtain an even more realistic life-cycle cost. However, that would necessitate building a much more complex model which is beyond the scope of this thesis. This thesis focuses on the impact of the long-term O&S costs on selection of alternative acquisition strategies.

B. COST SENSITIVITY ANALYSIS

Cost analysis can be accomplished by using objective means, such as statistical analysis, or subjective means, such as the use of expert opinion, or a combination of the two. The subjective analysis is perhaps the simplest, but not necessarily the least useful type of analysis. For most short-term decisions, where the cost of developing the model may out weigh the benefits gained, a subjective analysis may be more than adequate. A totally subjective analysis, however, may introduce both personal bias or preference and misconceptions based on prior experience. Extreme caution should be exercised when relying on the results of this type of analysis. Objective analysis, on the other hand, is based on models. Models are representations of an actual or conceptual system that involves mathematics, logical expressions, or computer simulations.[55] They can be used in a variety of applications at several different levels. One

of the most useful applications is the "what if" or sensitivity analysis.

Sensitivity analysis uses the inherent capabilities of a spreadsheet application to build a model which represents some real-world system or process. The cost sensitivity analysis is based on the degree of change in cost that results from changes in certain operating parameters of the system. Take the example of the component repair. Based on the case study program LCC assumptions, the average time between failures of a component is 10,000 hours. The cost-estimate of the repair will remain fixed, since the cost is based on repairing that component and not the number of components repaired. However, if the 10,000 hour value is changed to say, 8,000 hours, the most obvious and immediate effect is that the component must now be replaced and repaired more frequently. This in turn will increase the operating and support costs of the system over its entire useful life by some amount. The spreadsheet model allows the analyst to vary these parameters rather effortlessly.

The model, built in Lotus 1-2-3 Release 5 For Windows, and the results of the analysis are contained in Appendix F. It is important to note that the model used in this analysis is very simple and as a result, very limited. This, however, is by design and also the result of limited data availability. The objective is to provide an appreciation for the use of these techniques in complex decision-making. The model is constructed using data and

assumptions provided by NAVAIR. The data, however, is limited to the aggregate costs of the major LCC categories. Had more detailed data been available, the model could reflect a decomposition of the O&S costs and their assumptions similar to the cost element breakdown structure in Appendix B, instead of the gross total O&S cost-estimate. The inclusion of these elements at that level of subdivision, would greatly enhance the capabilities of the model.

C. COST UNCERTAINTY ANALYSIS

Cost uncertainty is an inherent element in the cost-estimate. The uncertainty is rooted in the potential for unplanned and unforeseen systems changes, schedule changes, and estimating errors. Early in the acquisition cycle, the impact of this uncertainty on the cost-estimate can be overwhelming. In an effort to get beyond this, the effects of uncertainty on cost is treated as probabilistic vice deterministic. This is accomplished by allowing the underlying assumptions of the cost-estimates to take on values that reflect some type of probability of occurrence. These values are then used as the basis for the cost-estimating relationship and an overall cost-estimate can be developed which has the highest probability of occurring. As previously noted in Chapter III, simulation is a method of achieving this forecast.

NAVAIR-estimated O&S life-cycle costs are depicted graphically in Appendix E. The O&S cost for the AH-4BW is $6.5 billion and $2.54 billion for the UH-4BN. Many of the underlying assumptions are based on the expert opinion of the analyst, generally in the form of adjustments to parametric or ROM cost-estimates. This does not imply that the opinion and experience of the analysts or the methods used are worthless. On the contrary, expert opinion is vital to the decision-making process. However, expert opinion all to often assumes factors will remain the same over time and more importantly, that these factors are deterministic in nature. The results of the two methods will be compared and contrasted.

Simulation allows the analyst to take the sensitivity analysis one step further. Instead of choosing a value randomly and observing the results, simulation allows the choosing of many values randomly and a determination of which values occurs most frequently. With the advent of the microcomputer, this simulation can now be performed very easily and quickly. Returning to the case study example, suppose a value of 6,500 hours was determined to be the most frequent occurrence of component fatigue life. This value can be said to be the most likely failure time of the component in question. This value could then be replaced back into the model to obtain a revised overall cost-estimate for the repair of the component over the life of the system. Also, the effects of economies of scale can be built into the model which can reflect a decrease in the

cost per unit as a result of learning curve or increase in inventory levels.

The simulation tool used for this analysis is Crystal Ball, a simulation add-in software package for Lotus 1-2-3 and Microsoft Excel. Crystal Ball, developed by Decisioneering Inc, is based on Monte Carlo simulation and effectively extends the forecasting capability of the model by allowing the assumptions to be treated as random variables. This allows the assumptions to be displayed as a range of possible outcomes with the probability of achieving each outcome. The versatility of Crystal Ball allows the analyst to choose from 12 different probability distributions and make a selection based on the conditions of the model and available data. For the purposes of this analysis, only the normal, triangular, and uniform distributions were used in an effort to match the assumptions to the data. The rationale behind each distribution selection and corresponding assumption follows.

Rationale for selection of a normal distribution:

- Some value, such as the NAVAIR assumption value, is the most likely value and the mean of the distribution.
- The assumption value is as likely to be above the mean as below the mean.
- The assumption value is more likely to be near the mean than far away.

The normal distribution was used for the inflation factor assumption because of its ability to represent many

different randomly occurring events. For the normal distribution, Crystal Ball's default value of the mean divided by ten was used as the standard deviation. This was accepted due to the lack of availability of the actual standard deviation. The software package allows the value to be easily changed to a value determined by the analyst.

Rationale for the selection of a triangular distribution:

- The minimum and maximum values of the assumption variable are fixed.
- The most likely value of the assumption variable falls between the minimum and maximum values, such that any value near the minimum or maximum is less likely to occur than those near the most likely value.

The triangular distribution was used both for the number of flight hours per aircraft per year and the projected life-cycle assumptions. The number of flight hours per aircraft per year variable assumed values between 0 and 480, with the most likely value the same as the NAVAIR assumption value. The purpose was to provide a range from zero hours flown to 40 hours flown per month. The project life-cycle had a minimum and maximum value of 15 years and 25 years respectively. Once again, the NAVAIR assumption value was treated as the most likely value. This allowed some consideration to be given to the uncertainty surrounding the development of the follow-on aircraft.

Rationale for the selection of a uniform distribution:

- The assumption factor is a probabilistic variable whose value has an equal probability of occurrence as any other value in the distribution.
- The shape of the distribution is defined by two fixed end points and an equal probability of occurrence.

The uniform distribution was used to define the assumption of a percentage of cost savings associated with the decrease in avionics repair from reduced vibration. The endpoints were given as 0% and 25%.

Crystal Ball allows the analyst the capability to determine how many trials to run for each simulation; for this model the number of trials used was 2,500. The results of the simulation were as follows: the overall O&S cost for the AH-4BW was $6.24 billion with a 8.5% chance of occuring, and $2.56 billion with a 9.2% chance of occurring for the UH-4BN. These values correspond to the value which had the highest frequency of occurrence during the simulation. The percentage represents the frequency of that value divided by the number of total trials. The cumulative frequencies represent the total probability that the cost lies somewhere between zero and the value. For example, for the UH-4BN, there is a 62% chance that the cost is between zero and $2,400 million.

In addition to the frequency graphs, Crystal Ball provides the capacity to conduct sensitivity analysis and determine which assumption variables have the greatest influence upon the forecasted O&S cost. This is graphically

depicted with the sensitivity charts in Appendix F. The larger the value associated with the assumption variable in the chart, the greater the relative influence on the forecasted value. As might be expected, the number of flight hours per aircraft per year had the largest impact on the forecast.

D. OTHER COST ANALYSES

There are other less in-depth analyses that can be performed separately or in conjunction with the methods described above and may yield some rather useful data for supporting cost-significant decisions. The basis of these analyses was discussed in Chapter III. An example of their possible use in this case study follows.

1. Net Present Value

Time value of money analysis is a very useful concept when dealing with long-range plans or long-term commitments. By treating the O&S costs in the outyears of the budget as future cash outflows, we can take the average annual cost, adjust it for the effects of a forecasted inflation rate and the forecast of any other factor which could affect this cost, and generate a cost in "then year" dollars. Other factors would include issues that affect the individual elements of the O&S costs separately. For instance, forecasted labor rates and learning curve theory on civilian

Naval Aviation Depot (NADEP) personnel. This new cost would represent how much it will cost to operate and support the system in each of the out years. This approach is more accurate than just using an average O&S cost over the life of the system.

2. Linear Regression

One of the many constraints of our case study program is the requirement that the LCC not rise above the levels used on the current system. An analysis based on linear regression allows us to use past data from O&M and MILPERS appropriations for the last 10 to 20 years, establish a trend, perform linear regression to obtain a relationship in the form of an equation, then forecast the amount of these appropriations anytime into the future. This is by no means the most accurate method of performing this task, however, it does provide a rough snapshot estimate of available funding. The forecasted LCC can then be compared to the forecasted appropriations data to derive a relationship in the form of a ratio. This relationship can also be derived for the trend data. The resulting ratios can then be compared and evaluated to provide feedback in an effort to remain within the desired limits.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. FINDINGS AND CONCLUSIONS

The spreadsheet model developed for this thesis allows the analyst to quickly and easily calculate the operations and support costs associated with the acquisition of a system during any time in the acquisition cycle. This calculation is based upon several assumptions which are treated as probabilistic variables in the model. The model can be constructed to take all of the LCC elements into consideration along with their inherent assumptions. With a basic understanding of probability, the simulation add-in software allows the analyst to go beyond the basic subjective solution derived from the deterministic, analyst-adjusted cost-estimate.

The strength of the model lies in its ability to provide the analyst with a tool to quickly and easily estimate life-cycle costs associated with competing alternative acquisition strategies. The model can be adjusted for a host of uncertainties, thereby reducing a portion of the risk involved in long-term endeavors.

The weakness of the model lies in its dependence on the quality of the assumption variables. The accuracy of the forecast is directly reflected in availability and plausibility of the assumptions. This model's lack of complexity is a testament to that statement. If many of the other assumptions had been available, the model would have

been able to provide a more accurate forecast for the two systems discussed and accurate LCC forecasts for the alternative systems. However, there will be a cost associated with developing these assumptions. In an event, the cost associated with making the model more reliable should not outweigh the benefit gained.

B. RECOMMENDATIONS

A more detailed evaluation of the underlying assumption is necessary to provide the model the most accurate input possible. As mentioned above, one weakness of this approach is that much is dependent upon the assumptions and their values. The probability distribution used and the values used in those distributions are all developed from the assumptions.

The merit of these analytical techniques is clear. The next step in the evolution of decision analysis should be taken without hesitation. The development of knowledge-based decision support systems (KSS) is already underway. These systems are developed as shells that are both reusable and generic to a particular type of acquisition project. KSS can deliver information, produce reliable answers quickly, reduce the costs associated with the generation of information, make more effective use of existing models and data bases, result in better decisions, facilitate better presentations of recommendations, and function as a library for models and data.[56] The U. S.

Coast Guard has already initiated a project to develop KSS for its acquisition decisions.

C. FOLLOW-ON QUESTIONS

The question this thesis attempted to answer has surfaced a flurry of other issues. This was an expected outcome of the research. One area of particular concern is the manpower issues surrounding the acquisition strategies. Had the manning level requirements data been available, an assumption variable could have been developed and included in the model. This may have had a large impact on the O&S cost. The sensitivity analysis would have reflected the relative sensitivity of this variable on the model.

Training and maintenance manning are key issues that need to be resolved. With the addition of a H-60 fleet in the Marine Corps, will the long-term costs associated with training the mechanics, acquiring the correct number of personnel in the right mix to support the aircraft, and the HMLA-unique three-way split of the squadron assets for deployment, cause an increase in the life cycle costs of the H-60? The model could be developed to project this situation.

APPENDIX A. GLOSSARY

A

acquisition category - Categories established to facilitate decentralized decision making and execution and compliance with statutorily imposed requirements. The categories determine the level of review, decision authority, and applicable procedures

acquisition life cycle - Five phases, each proceeded by a milestone or other decision point, during which a systems goes through research, development, test and evaluation and production. These five phases are: (1) Concept Exploration/Definition, (2) Demonstration and Validation, (3) Engineering and Manufacturing and Development, (4) Production and Deployment and (5) Operations and Support.

acquisition strategy - A business and technical management approach designed to achieve program objectives within resource constraints imposed. It is the framework for planning, directing, and managing a program. It provides a master schedule for research, development, test, production, fielding and other activities essential for program success, and for formulating functional plans, and strategies, e.g., Test and evaluation Master Plan, Acquisition Plan, competition, prototyping, etc.

B

baseline - Defined quantity or quality used as starting point for subsequent efforts and progress measurement. Can be a technical cost or schedule baseline. See Performance Measurement Baseline and Acquisition Program Baseline.

baseline cost estimate - A detailed estimate of acquisition and ownership costs normally required for high level decisions. This estimate is performed early in the program and serves as the basepoint for all subsequent tracking and auditing purposes.

budget - A comprehensive financial plan for the Federal Government, encompassing the totality of Federal receipts and outlays (expenditures). The budget documents routinely include the on-budget and off-budget amounts and combine them to derive a total of Federal fiscal activity, and the focus of the budget documents is on the combined totals. Also a plan of operations for a fiscal period in terms of (a) estimated costs, obligations, and expenditures; (b) source of funds for financing including anticipated reimbursements and other resources; and (c) history and workload data for the projected program and activities.

C

commonality - A quality which applies to material or systems possessing like and interchangeable characteristics enabling each to be utilized or operated and maintained by personnel trained on the others without additional specialized training; and/or having interchangeable repair parts and/or components; and applying to consumable items interchangeably equivalent without adjustment.

cost analysis - An analysis and evaluation of each element of cost in a contractor's proposal to determine reasonableness.

cost analysis improvement group - Organization within the office of the ASD (PA&E) which advises the DAB on matters concerning the estimation, review and presentation of cost analysis of future weapon systems. The CAIG also develops common cost estimating procedures for DoD.

cost avoidance - An action taken in the immediate time frame that will decrease costs in the future. For example, an engineering improvement that increases the mean time between failures and thereby decreasing operating support costs can be described as a cost avoidance action. It is possible for the engineering change to incur higher costs in the immediate time frame. As long as net total life cycle costs are less, it is a cost avoidance action. The amount of the cost avoidance is determined as the difference between two

estimated cost patterns, one before the change and the one after.

cost and operational effectiveness analysis - An analysis of the costs and operational effectiveness of alternative material systems to meet a mission need and the associated program for acquiring each alternative.

cost/benefit - A criterion for comparing programs and alternatives when benefits can be valued in dollars. Also referred to as benefit-cost ratio which is a function of equivalent benefits and equivalent costs. Useful in the search for an optimal program mix which produces the greatest number of benefits over costs.

cost breakdown structure - A system for subdividing a program into (a) hardware elements and sub-elements; (b) functions and subfunctions; and (c) cost categories to provide for more effective management and control of the program.

cost effectiveness - A measure of the operational capability added by a system as a function of its life-cycle cost.

cost estimate - A judgment or opinion regarding cost of an object, commodity or service. A result of product of an estimating procedure which specifies the expected dollar cost required to perform a stipulated task or to acquire an item. A cost estimate may constitute a single value or a range of values.

cost estimating relationship - A mathematical relationship that defines cost as a function of one or more parameters such as performance, operating characteristics, physical characteristics, etc.

cost model - A compilation of cost estimating logic that aggregates cost estimating details into a total cost estimate.

D

design-to-cost - Management concept wherein rigorous cost goals are established during development and the control of systems costs (acquisition, operating, and support) to these goals is achieved by practical tradeoffs between operational capability, performance, costs and schedule. Cost, as a key design parameter, is addressed on a continuing basis and as an inherent part of the development and production process.

disposal - The act of getting rid of excess, surplus, scrap, or salvage property under proper authority. Disposal may be accomplished by, but not limited to, transfer, donation, sale, declaration, abandonment, or destruction.

E

economies of scale - Reductions in unit cost of output resulting from the production of additional units. Stem from (1) increased specialization of labor as volume of output increases, (2) decreased unit costs of materials, (3) better utilization of management, (4) acquisition of more efficient equipment, and (5) greater use of by-products.

effective competition - A marketplace condition that results when two or more manufacturing sources are acting independently of each other.

effectiveness - The extent to which the goals of the system are attained, or the degree to which a system can be elected to achieve a set of specific mission requirements. Also, an output of the cost effectiveness analysis.

F

flyaway costs - Costs related to production of a useable end item of military hardware. Includes the cost of procuring the basic unit (airframe, hull, chassis, etc.), an allowance for changes, propulsion equipment, electronics, armament, and other installed government-furnished equipment, and nonrecurring "start-up" production costs. Equates to Rollaway and Sailaway cost.

I

initial spares - Items procured for logistics support of a system during its initial period of operation.

integrated logistic support - A disciplined, unified, and iterative approach to the management and technical activities necessary to integrate support considerations into system and equipment design; develop support requirements that are related consistently to readiness objectives, to design, and to each other, acquire the required support; and provide the required support during the operational phase at minimum cost.

L

learning/improvement curve - A mathematical way to explain and measure the rate of change of cost (in hours or dollars) as a function of quantity.

life-cycle cost - The total cost to the government of acquisition and ownership of that system over its useful life. It includes the cost of development, acquisition, support, and, where applicable, disposal.

long-lead items/long-lead time materials - Those components of a system or piece of equipment for which the times to design and fabricate are the longest, and, therefore, to which an early commitment of funds may be desirable in order to meet the earliest possible data of system completion. Might be ordered during EMD to arrive for production start.

M

Marine Air-Ground Task Force A task organization of Marine forces (division, aircraft wing and service support groups) under a single command and structured to accomplish a specific mission. The MAGTF components will normally include command, aviation combat, ground combat, and combat service support elements (including Navy Support Elements).

N

non-recurring costs - (1) costs which are not proportional to the number of units produced. (2) a one-time costs that will occur on a periodic basis for the same organization. Nonrecurring costs include (a) preliminary design effort; (b) design engineering (c) all partially completed reporting elements manufactured for tests; (3) training of service instructor personnel.

O

operating and support (O&S) cost - Those resources required to operate and support (O&S) a system, subsystem, or a major component during its useful life in the operational inventory.

operational requirements document - Documents the users objectives and minimum acceptable requirements for operational performance of a proposed concept or system. Format has been standardized across all DoD components by DoDI 5000.11 and DoD 5000.2-M.

R

reliability - The ability of a system and its part to perform its mission without failure, degradation, or demand on the support system.

S

simulation - A simulation is a method for implementing a model. It is the process of conducting experiments with a model for the purpose of understanding the behavior of the system modeled under the selected conditions or of evaluating various strategies for the operation of the system within the limits imposed by developmental or operational criteria. simulation may include the use of analog or digital devices, laboratory models, or "testbed" sites. Simulations are usually programmed for solution on a computer; however, in the broadest sense, military exercises and wargames are also simulations.

supportability - The degree to which system design characteristics and planned logistics resources, including manpower, meet system peacetime readiness and wartime utilization requirements.

V

validation - (1) the process by which the contractor (or as otherwise directed by the DoD component procuring activity) tests a TM for technical accuracy and adequacy. (2) the procedure of comparing input and output against an edited file and evaluating the result of the comparison by means of a decision table established as a standard. (3) the process by which the preparing activity for a document determines that the document reflects.

APPENDIX B. ALTERNATIVE AIRCRAFT OVERVIEW

NAVAIRSYSCOM

Concept Analysis, Evaluation and Planning Department

Aircraft Overview

	AH-1W Cobra	AH-4BW *	AH-64D Apache *	RAH-66 Comanche *
TOGW	14750	16700	17650	12769
ZFZP WT	11212	12189	13186	8620
Max Internal Fuel Capacity	2067	2067	2442	2054
Max External Fuel Capacity (lbs)	979	979	5980	6120
Full Weapons Arsenal	Hellfire (8) TOW 20 mm / Rockets AIM-9H/L/M Sidewinder AGM-122A Sidearm	Hellfire (16) TOW 20 mm / Rockets AIM-9H/L/M Sidewinder AGM-122A Sidearm	Laser/RF Hellfire (16) Air-to-Air 4 wingtip, addn w/ pylon 70 mm / Rockets 30 mm Cannon	Laser/RF Hellfire (14) AIM-92 Stinger Army Counter Air 3-barrel 20 mm with lead-reticle target capabilitly
Speeds (3K'/Hot Day, Avg Msn)				
Best Range	127-129		110-118	Spec=165
Maximum Continuous	130-140		120-130	Spec Dash = 175

* MILSTD 1760 Interface permits use with many NATO weapons.

(8)

NAVAIRSYSCOM Concept Analysis, Evaluation and Planning Department

Attack Helicopter Alternatives

6 June Reassessment

- AH-1W
- 4BW

Other Service Variants

- AH-64D Apache (w/o Longbow)
- RAH-66 Comanche (w/o Longbow)

Missions:

- Anti-armor
- Fire Support
- Escort

Measures of Performance: (Std Day & Hot Day)

- Payload vs. Radius
- Time on Station vs. Radius

NAVAIRSYSCOM Concept Analysis, Evaluation and Planning Department

Cost
(Constant FY95$ Millions)

Quantity	*AH-1W 1* (180)	*AH-1(4BW) 2* (180)	*AH-64D 3* (180)	*RAH-66 4* (180)
R & D	$81	$344 - $553		
Production	$455	$980 - $1,082	6000 - 7200	$4,800 - $5,800
Total Procurement	$536	$1,324 - $1,635	- -	- -
O&S	$7,100	$6,500 $6,700	- -	- -
Total LCC	$7,636	$7,824 $8,335		

1 IWS COSTS INCLUDED
2 ASSUME 4BN/4BW CONCURRENT; INCLUDES $12M BELL ESTIMATE FOR SIX STORE STATION WING
3 ARMY/CONTRACTOR; ROM FOR MARINIZATION EFFORTS & FACTOR FOR UNKNOWNS
3 ARMY PM; ROM: FOLDING ROTOR, LANDING GEAR, MARINIZATION EFFORTS & FACTOR FOR UNKNOWNS

(11)

NAVAIRSYSCOM

Concept Analysis, Evaluation and Planning Department

Utility Helicopter Alternatives

6 June Reassessment

- UH-1N
- UH-1 (-412)
- UH-1 (4BN)
- CH-60M^2

Other Service Variants

- HH-60 Seahawk
- UH-60L Blackhawk

Troop Insert Mission Payload (lbs)- 8 Combat Marines (1,880)
Troop Insert Mission Kit (lbs) -1033

•Flare/Chaff	23
• Gun Mounts (2)	134
• .50 Cal MG w/500 RDS	298
• 7.62 mm MG w/500 RDS	90
• ALQ-144 XMTR	28
• Rope Suspension Gantry (2)	300
• NTIS (FLIR)	160

Life Cycle Cost
(Constant FY95$ Millions)

	UH-1N[1]	UH-1(412)[2]	UH-1(4BN)	CH-60(L)[3]	CH-60(H)[4]
Quantity	(100)	(105)	(100)	(100)	
R & D	$0	N/E	$120 - $155	N/E	
Production	$196	$390	$730 - $1,000	$1,300 - $1,600	$1,400 - $1,700
Total Procurement	$196	-	$850 - $1,155	$1,300 - $1,600	$1,400 - $1,700
O&S	$2,400	$2,554	$2,500 - $2,600	-	-
Total LCC	-	-	$4,200 - $4,910	-	-

1 AIR-4.2, May 95
2 NAWCAD, April 94
3 AIR-4.2 Gross ROM, June 95
4 AIR-4.2 Gross ROM, June 95

(20)

APPENDIX C. O&S COST ELEMENT BREAKDOWN STRUCTURE

Section I. O&S Cost Elements

CEBS #	Level 1 2 3 4
0000	Operating and Support
1000	Personnel
1100	Officers
1110	Pilots
1120	Non-Pilots
1200	Enlisted
1210	Aircrew
1220	Squadron Administration and Operations
1230	Maintenance Supervision
1240	Maintenance Administration
1250	O-Level Direct Maintenance
1260	T-Level Direct Maintenance
2000	Operating Consumables
2100	POL
2200	Training Expendables
3000	Maintenance Consumables
3100	Airframe
3200	Avionics
3300	Power Plant
3400	Other (Specify)
4000	Depot Maintenance
4100	Airframe Rework
4200	Engine Repair/Rework
4300	Component Repair
4310	Airframe
4320	Avionics
4400	Other (Specify)
5000	Replenishment Spares
5100	Airframe

5200	Avionics
5300	Power Plant
5400	Other (Specify)
6000	Support Equipment Maintenance
7000	Training Equipment Maintenance
8000	Software Support
9000	Contractor Support Personnel
9100	Contractor Maintenance Support Personnel
9200	Contractor Logistics Support Personnel

Section II. Definitions

1000 **Personnel** - The cost of full the complement of personnel required to operate and support the squadron. It includes the number of personnel necessary to meet combat readiness, training and administrative requirements such as leave, sickness, TDY, etc. Both the cost and number of people should be presented for all levels of personnel in this cost element structure.

1100 **Officers** - The cost and number of the full complement of officer personnel required to operate and support the squadron.

1110 **Pilots** - The cost and number of squadron Aviation Officer Pilots.

1120 **Non-Pilots** - The cost and number of squadron officers who are not pilots.

1200 **Enlisted** - The cost and number of the full complement of enlisted personnel required to operate and support the squadron.

1210 **Aircrew** - The cost and number of squadron enlisted personnel assigned aircrew billets.

1220 **Squadron Administration and Operations** - The cost and number of squadron enlisted personnel in the administrative, executive, operations, integrated services, etc. departments.

1230 **Maintenance Administration** - The cost and number of squadron enlisted personnel whose duties are associated with clerical, material control, quality assurance and with I level administration.

1240 **Maintenance Supervision** - The cost and number of squadron enlisted personnel who direct and supervise 0 level maintenance requirements (e.g., electronics maintenance supervisor, safety equipment maintenance supervisor, or power plant maintenance supervisor).

1250 **O Level Direct Maintenance** - The cost and number of squadron enlisted personnel associated with direct maintenance of squadron aircraft at the organizational level. Duties include performance of scheduled and unscheduled maintenance and support actions associated with direct maintenance of squadron aircraft plus the associated tasks required for set up, transportation, servicing, turnaround, inspection, and supply/maintenance records transactions.

1260 **I Level Direct Maintenance** - The cost and number of enlisted personnel associated with all intermediate level direct maintenance of squadron aircraft. Duties include performance of I level maintenance plus the associated tasks required for set up, transportation, inspection, and supply/maintenance records transactions. These personnel may not all be assigned to the squadron, they may be part of a SEA-OP-DET.

2000 **Operating Consumables** - The cost of consumables used in operating the aircraft and it's associated equipment.

2100 **POL** - The cost of aviation petroleum, oil and lubricants (POL) required to support the peacetime flying hour program.

2200 **Training Expendables** - The cost of items expended by the squadron in peacetime training operations. Includes such items as live and inert ammunition, bombs, rockets, missiles, torpedoes and sonobuoys.

3000 **Maintenance Consumables** - The cost of all non-repairable (consumable) material used in organizational and intermediate maintenance and support of squadron aircraft. Excludes the cost of repairable items that are attrited, as this cost is included in replenishment spares.

3100 **Airframe** - The cost of all maintenance consumables associated with the airframe.

3200 **Avionics** - The cost of all maintenance consumables associated with the avionics.

3300 **Power Plant** - The cost of all maintenance consumables associated with the power plant.

3400 **Other** - The cost of all maintenance consumables not covered by the above definitions.

4000 **Depot Maintenance** - The total cost of labor, material and overhead for depot level maintenance of the aircraft airframe, engine and components.

4100 **Airframe Rework** - The total cost including labor, material and overhead of depot level rework, including both scheduled and unscheduled maintenance to assure the required material condition of the airframe. This would include Standard Depot Level Maintenance (SDLM) which consists of depot level rework at specific intervals during the aircraft's service life. Also included are depot level inspections such as Age Exploration and Aircraft Service Period Adjustment and their associated maintenance.

4200 **Engine Repair/Rework** - The total cost, including labor, material and overhead of scheduled and unscheduled depot level repair and rework of the engine, engine modules and engine components.

4300 **Component Repair/Rework** - The total cost including labor, material and overhead of depot level component repair and rework covering both scheduled periodic maintenance and unscheduled maintenance of airframe and avionics components.

4310 **Airframe** - The cost of airframe component repair and rework.

4320 **Avionics** - The cost of avionics component repair and rework.

4400 **Other** - The cost of any depot level maintenance not covered by the above definitions.

5000 **Replenishment Spares** - The cost of replacing normally repairable items that are disposed of in attrition and depot survey as beyond economical repair.

5100 **Airframe** - The cost of all replenishment spares associated with the airframe.

5200 **Avionics** - The cost of all replenishment spares associated with the avionics.

5300 **Power Plant** - The cost of all replenishment spares associated with the power plant.

5400 **Other** - The cost of all replenishment spares not associated with the above definitions.

6000 **Support Equipment Maintenance** - The total cost of maintaining common and peculiar support equipment which is used to support aircraft at all levels of maintenance.

7000 **Training Equipment Maintenance** - The total cost of maintaining all program training equipment at all levels of maintenance.

8000 **Software Support** - The cost of maintaining and updating all weapon system computer programs. Includes the cost associated with the aircraft, support and test equipment, flight trainers, and any other system software.

9000 **Contractor Support Personnel** - The cost of contractor personnel required to perform maintenance and logistics support functions.

9100 **Contractor Maintenance Support Personnel** - The cost of contractor personnel required to support maintenance functions. Both the cost and number of personnel should be presented by function. Contract personnel performing full time maintenance functions at the depot level should be documented as a depot cost.

9200 **Contractor Logistics Support Personnel** - The cost of contractor personnel performing logistics functions such as

supply support, management, etc. Both the cost and number of personnel should be presented by function.

APPENDIX D. LIFE-CYCLE COST ASSUMPTIONS

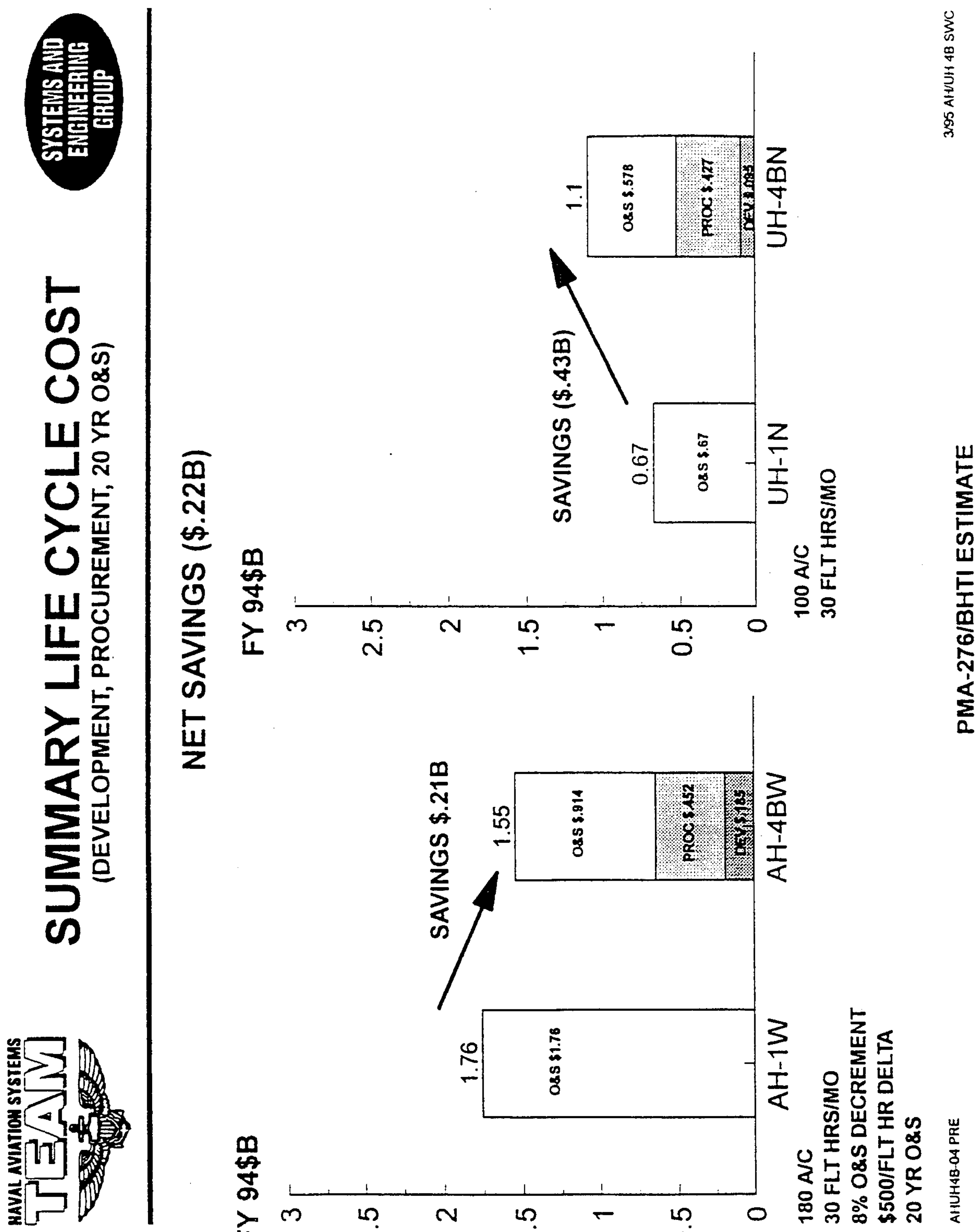
Section I. Attack Helicopter

Aircraft Fleet	230 Aircraft
Flight Hours per Aircraft	360 hours/Year
Modified Aircraft per Year	24 Aircraft
Inflation	3 Percent
AH-1W Metal Blade Life	2,200 Hours
AH-1W Metal Blade Overhaul	1,100 Hours
AH-1W Unscheduled Maintenance Increase ..	8 Percent/Yr
AH-1(4B)W Component Fatigue Lives	10,000 Hours
AH-1(4B)W Transmission TBO	5,000 Hours
SDLM Credit at AH-1(4B)W Modification	$200,000
AH-1(4B)W SDLM Elimination	1
AH-1(4B)W Follow-on SDLM Cost Reduction ..	$100,000 EA

Section II. Light Assault Helicopter

Aircraft Fleet	100 Aircraft
Flight Hours per Aircraft	360 hours/Year
Modified Aircraft per Year	12 Aircraft
Inflation	3 Percent
UH-1N Metal Blade Life	2,200 Hours
UH-1N Metal Blade Overhaul	1,100 Hours
UH-1N Unscheduled Maintenance Increase	8 Percent/Yr
UH-1(4B)N Component Fatigue Lives	10,000 Hours
UH-1(4B)N Transmission TBO	5,000 Hours
SDLM Credit at UH-1(4B)N Modification	$400,000
UH-1(4B)N SDLM Elimination	1
UH-1(4B)N Follow-on SDLM Cost Reduction	$330,000 EA

APPENDIX E. NAVAIR LIFE-CYCLE COST ESTIMATES



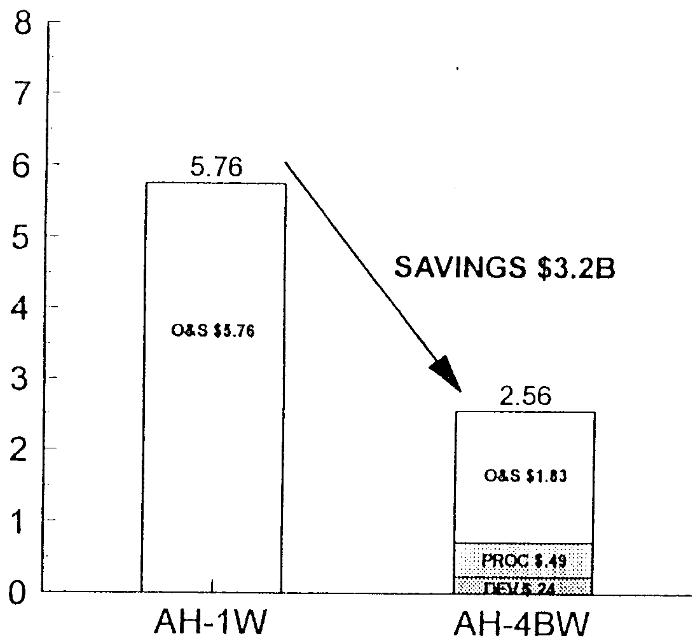
NAVAL AVIATION SYSTEMS TEAM

SUMMARY LIFE CYCLE COST

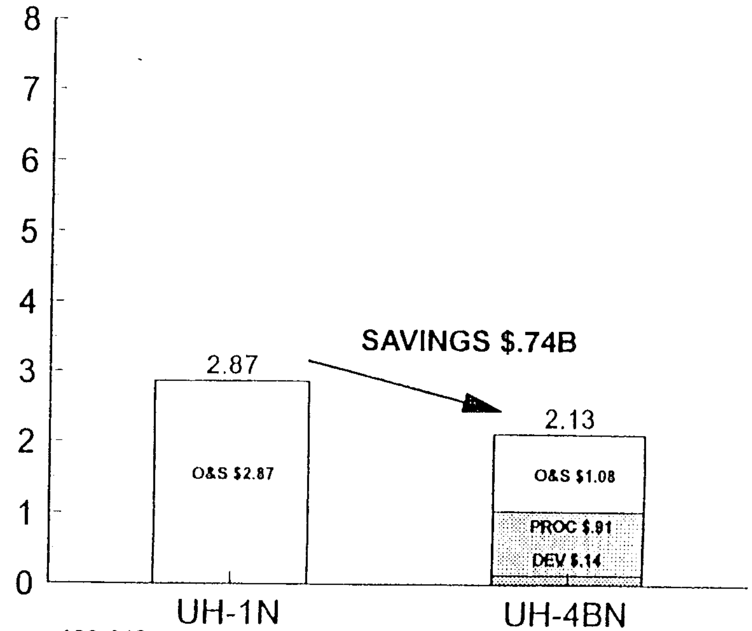
(DEVELOPMENT, PROCUREMENT, 20 YR O&S)

SYSTEMS AND ENGINEERING GROUP

NET SAVINGS $3.94B



180 A/C
30 FLT HRS/MO
8% O&S DECREMENT
$500/FLT HR DELTA
20 YR O&S



100 A/C
30 FLT HRS/MO

AHUH4B-04 PRE

PMA 276/BHTI ESTIMATE

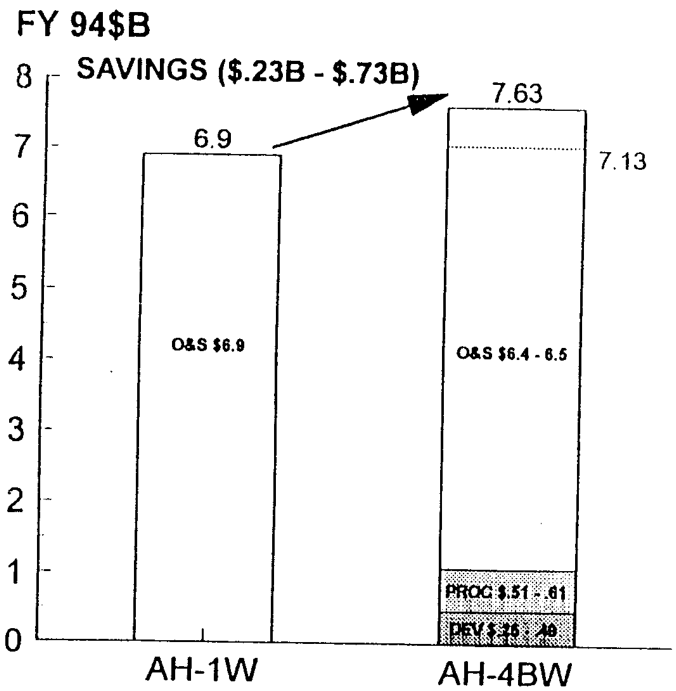
3/95 AH/UH 4B SWC

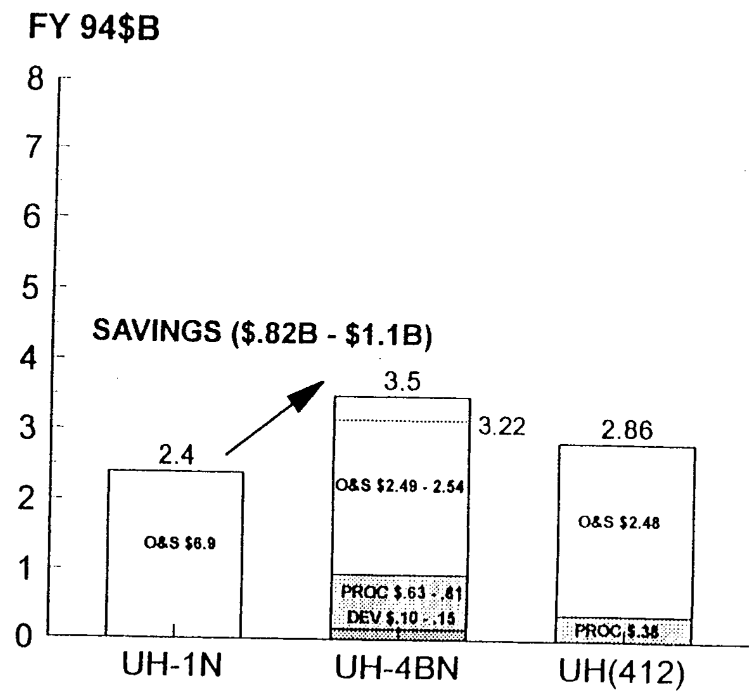
NAVAL AVIATION SYSTEMS TEAM

SUMMARY LIFE CYCLE COST
(DEVELOPMENT, PROCUREMENT, FULL LC O&S)

SYSTEMS AND ENGINEERING GROUP

NET SAVINGS ($1.05B - $1.83B)





180 A/C
21.7 FLT HRS/MO (AH-1W, AH-4BW)
0-25% REDUCED AVIONICS VIBRATION (AH-4BW)
FULL LIFE CYCLE O&S (AH-1W, AH-4BW)

100 A/C (UH-1N, UH-4BN) / 105 A/C (UH412)
27.9 FLT HRS/MO (UH-1N, UH-4BN) / 27.1 FLT HRS/MO (UH412)
0-25% REDUCED AVIONICS VIBRATION (UH-4BN)
FULL LIFE CYCLE O&S (UH-1N, UH-4BN) / 20 YEAR 0&S (UH412)

AHUH4B-05 PRE

AIR-4.2 ESTIMATE

3/95 AH/UH 4B SWC

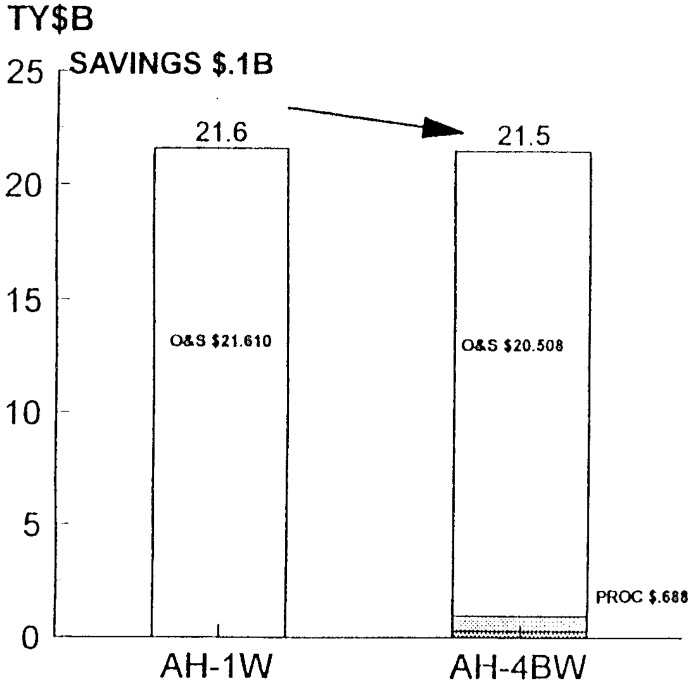
NAVAL AVIATION SYSTEMS TEAM

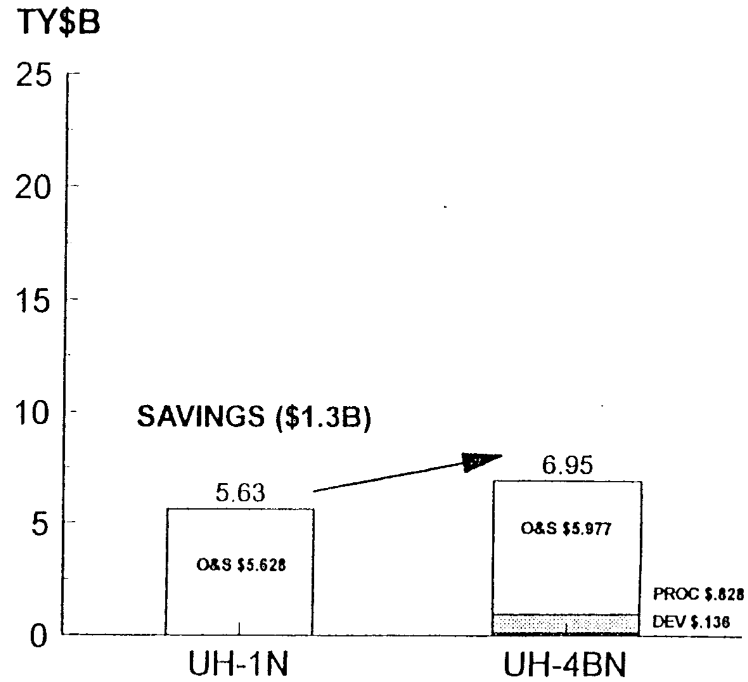
SUMMARY LIFE CYCLE COST

(DEVELOPMENT, PROCUREMENT, FULL LC O&S)

SYSTEMS AND ENGINEERING GROUP

NET SAVINGS ($1.2B)





180 A/C
21.7 FLT HRS/MO (AH-1W, AH-4BW)
0-25% REDUCED AVIONICS VIBRATION (AH-4BW)
FULL LIFE CYCLE O&S (AH-1W, AH-4BW)

100 A/C (UH-1N, UH-4BN)
27.9 FLT HRS/MO (UH-1N, UH-4BN)
0-25% REDUCED AVIONICS VIBRATION (UH-4BN)
FULL LIFE CYCLE O&S (UH-1N, UH-4BN)

AHUH4B-05 PRE

PMA-276 REVISED ESTIMATE

3/95 AH/UH 4B SWC

APPENDIX F. O&S COST MODEL

LONG TERM OPERATIONS & SUPPORT COST ANALYSIS

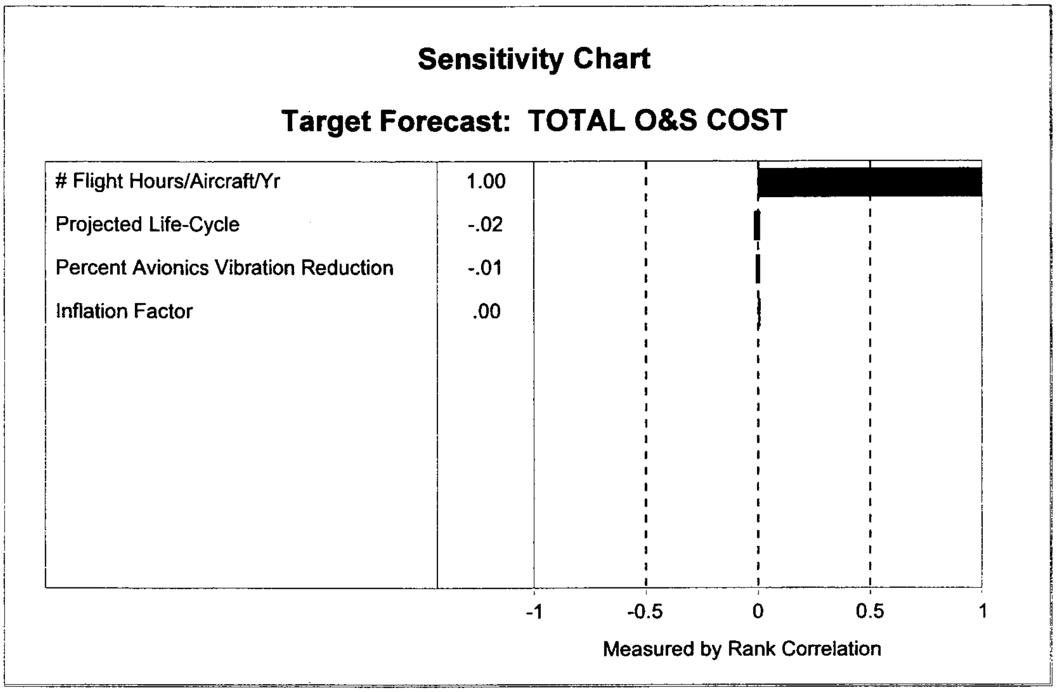
AH-4BW All Dollar Values in Millions

	Value	Assumptions
O&S Cost/Fighlt Hour	$0.01	
# Flight Hours/Aircraft/Yr	260.40	Triangular Distribution, Minimum-0, Maximum-480
Inflation Factor	3.00%	Normal Distribution, Mean-3%, Std Dev-0.3%
Reduced Avionic Vib Save	25.00%	Uniform Distribution, Minimum-0%, Maximum-25%
Projected Life-Cycle	20	Triangular Distribution, Minimum-15, Maximum-25

Items	Year						Year		
	0	1	2	3	4	5	6	7	8
O&S Cost/Flight Hour		$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01
# Flight Hours/Aircraft/Yr		260.40	260.40	260.40	260.40	260.40	260.40	260.40	260.40
# of Aircraft per Year		4	6	12	24	24	24	24	24
Cumulative # of Aircraft		4	10	22	46	70	94	118	142
Annual O&S Cost		$9.80	$24.51	$53.92	$112.75	$171.57	$230.39	$289.22	$348.04
Inflation Factor		1.03	1.06	1.09	1.13	1.16	1.19	1.23	1.27
Reduced Avionic Vib Save		$0.15	$0.38	$0.83	$1.73	$2.64	$3.54	$4.45	$5.35
Annual O&S Cost	$0	$9.65	$24.13	$53.09	$111.01	$168.93	$226.85	$284.77	$342.68
Inflation Adjust O&S Cost	$0	$9.94	$25.60	$58.02	$124.94	$195.84	$270.87	$350.23	$434.10
TOTAL O&S COST FY94$	$6,400.00								
TOTAL O&S COST TY$	$9,469.20								

		Year				Year				Year	
9	10	11	12	13	14	15	16	17	18	19	20
$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01
260.40	260.40	260.40	260.40	260.40	260.40	260.40	260.40	260.40	260.40	260.40	260.40
24	14	0	0	0	0	0	0	0	0	0	0
166	180	180	180	180	180	180	180	180	180	180	180
$406.86	$441.18	$441.18	$441.18	$441.18	$441.18	$441.18	$441.18	$441.18	$441.18	$441.18	$441.18
1.30	1.34	1.38	1.43	1.47	1.51	1.56	1.60	1.65	1.70	1.75	1.81
$6.26	$6.79	$6.79	$6.79	$6.79	$6.79	$6.79	$6.79	$6.79	$6.79	$6.79	$6.79
$400.60	$434.39	$434.39	$434.39	$434.39	$434.39	$434.39	$434.39	$434.39	$434.39	$434.39	$434.39
$522.70	$583.78	$601.30	$619.33	$637.91	$657.05	$676.76	$697.07	$717.98	$739.52	$761.70	$784.55

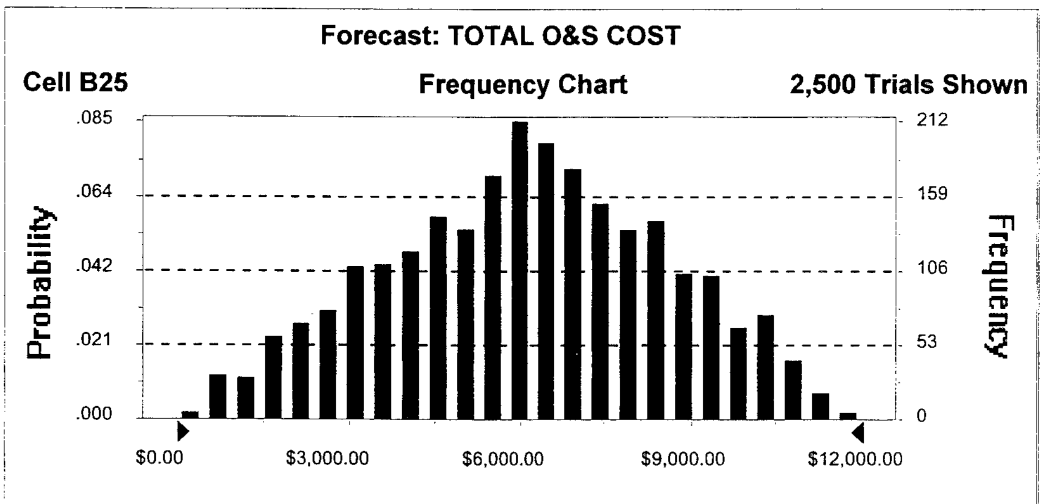
Crystal Ball Report
Simulation started on 12/7/95 at 19:18:35
Simulation stopped on 12/7/95 at 19:21:30



Forecast: TOTAL O&S COST Cell: B25

Summary:
Display Range is from $0.00 to $12,000.00
Entire Range is from $120.31 to $11,714.09
After 2,500 Trials, the Std. Error of the Mean is $49.06

Statistics:	Value
Trials	2500.00
Mean	6117.09
Median (approx.)	6163.13
Mode (approx.)	5917.20
Standard Deviation	2453.10
Variance	6017698.24
Skewness	-0.09
Kurtosis	2.38
Coeff. of Variability	0.40
Range Minimum	120.31
Range Maximum	11714.09
Range Width	11593.78
Mean Std. Error	49.06



Forecast: TOTAL O&S COST (cont'd) Cell: B25

Percentiles:

Percentile	Value (approx.)
0.00%	120.31
10.00%	2737.19
20.00%	3883.46
30.00%	4768.86
40.00%	5569.39
50.00%	6163.13
60.00%	6779.00
70.00%	7501.68
80.00%	8368.46
90.00%	9384.29
100.00%	11714.09

Frequency Counts:

Frequency:

Freq.	Group	Start Value	End Value	Prob.
0		-Infinity	$0.00	0.000000
5	1	$0.00	$480.00	0.002000
32	2	$480.00	$960.00	0.012800
30	3	$960.00	$1,440.00	0.012000
60	4	$1,440.00	$1,920.00	0.024000
69	5	$1,920.00	$2,400.00	0.027600
78	6	$2,400.00	$2,880.00	0.031200
109	7	$2,880.00	$3,360.00	0.043600
110	8	$3,360.00	$3,840.00	0.044000
120	9	$3,840.00	$4,320.00	0.048000
144	10	$4,320.00	$4,800.00	0.057600
135	11	$4,800.00	$5,280.00	0.054000
174	12	$5,280.00	$5,760.00	0.069600
212	13	$5,760.00	$6,240.00	0.084800
198	14	$6,240.00	$6,720.00	0.079200
178	15	$6,720.00	$7,200.00	0.071200
154	16	$7,200.00	$7,680.00	0.061600
135	17	$7,680.00	$8,160.00	0.054000
142	18	$8,160.00	$8,640.00	0.056800
104	19	$8,640.00	$9,120.00	0.041600
103	20	$9,120.00	$9,600.00	0.041200
65	21	$9,600.00	$10,080.00	0.026000
75	22	$10,080.00	$10,560.00	0.030000
43	23	$10,560.00	$11,040.00	0.017200
20	24	$11,040.00	$11,520.00	0.008000

Forecast: TOTAL O&S COST (cont'd)

Cell: B25

Freq.	Group	Start Value	End Value	Prob.
5	25	$11,520.00	$12,000.00	0.002000
0		$12,000.00	+Infinity	0.000000
2500 Total				1.000000

Cumulative:

Freq.	Group	Start Value	End Value	Prob.
0		-Infinity	$0.00	0.000000
5	1	$0.00	$480.00	0.002000
37	2	$480.00	$960.00	0.014800
67	3	$960.00	$1,440.00	0.026800
127	4	$1,440.00	$1,920.00	0.050800
196	5	$1,920.00	$2,400.00	0.078400
274	6	$2,400.00	$2,880.00	0.109600
383	7	$2,880.00	$3,360.00	0.153200
493	8	$3,360.00	$3,840.00	0.197200
613	9	$3,840.00	$4,320.00	0.245200
757	10	$4,320.00	$4,800.00	0.302800
892	11	$4,800.00	$5,280.00	0.356800
1066	12	$5,280.00	$5,760.00	0.426400
1278	13	$5,760.00	$6,240.00	0.511200
1476	14	$6,240.00	$6,720.00	0.590400
1654	15	$6,720.00	$7,200.00	0.661600
1808	16	$7,200.00	$7,680.00	0.723200
1943	17	$7,680.00	$8,160.00	0.777200
2085	18	$8,160.00	$8,640.00	0.834000
2189	19	$8,640.00	$9,120.00	0.875600
2292	20	$9,120.00	$9,600.00	0.916800
2357	21	$9,600.00	$10,080.00	0.942800
2432	22	$10,080.00	$10,560.00	0.972800
2475	23	$10,560.00	$11,040.00	0.990000
2495	24	$11,040.00	$11,520.00	0.998000
2500	25	$11,520.00	$12,000.00	1.000000
2500		$12,000.00	+Infinity	1.000000

End of Forecast

Assumptions

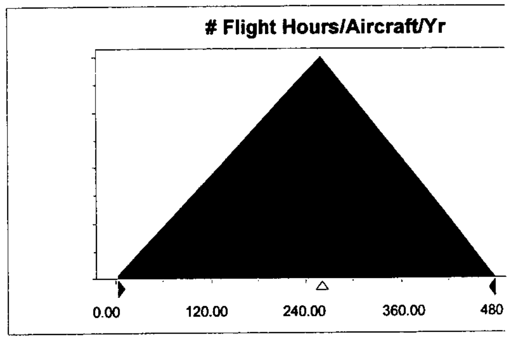
Assumption: # Flight Hours/Aircraft/Yr

Cell: B9

Triangular distribution with parameters:

Minimum	0.00
Likeliest	260.40
Maximum	480.00

Selected range is from 3.20 to 480.00
Mean value in simulation was 246.99



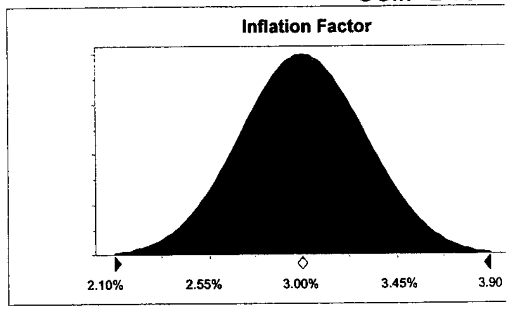
Assumption: Inflation Factor

Cell: B10

Normal distribution with parameters:

Mean	3.00%
Standard Dev.	0.30%

Selected range is from -Infinity to +Infinity
Mean value in simulation was 2.99%



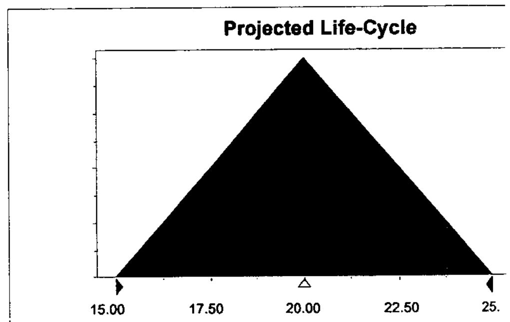
Assumption: Projected Life-Cycle

Cell: B12

Triangular distribution with parameters:

Minimum	15.00
Likeliest	20.00
Maximum	25.00

Selected range is from 15.00 to 25.00
Mean value in simulation was 19.98



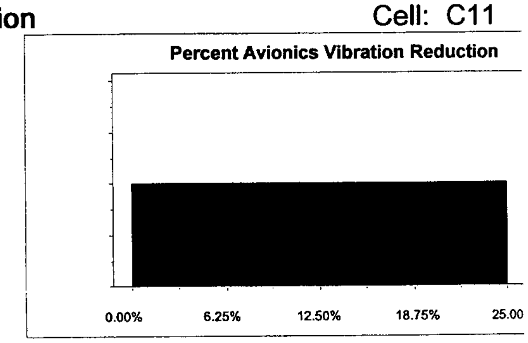
Assumption: Percent Avionics Vibration Reduction

Cell: C11

Uniform distribution with parameters:

Minimum	0.00%
Maximum	25.00%

Mean value in simulation was 12.68%



End of Assumptions

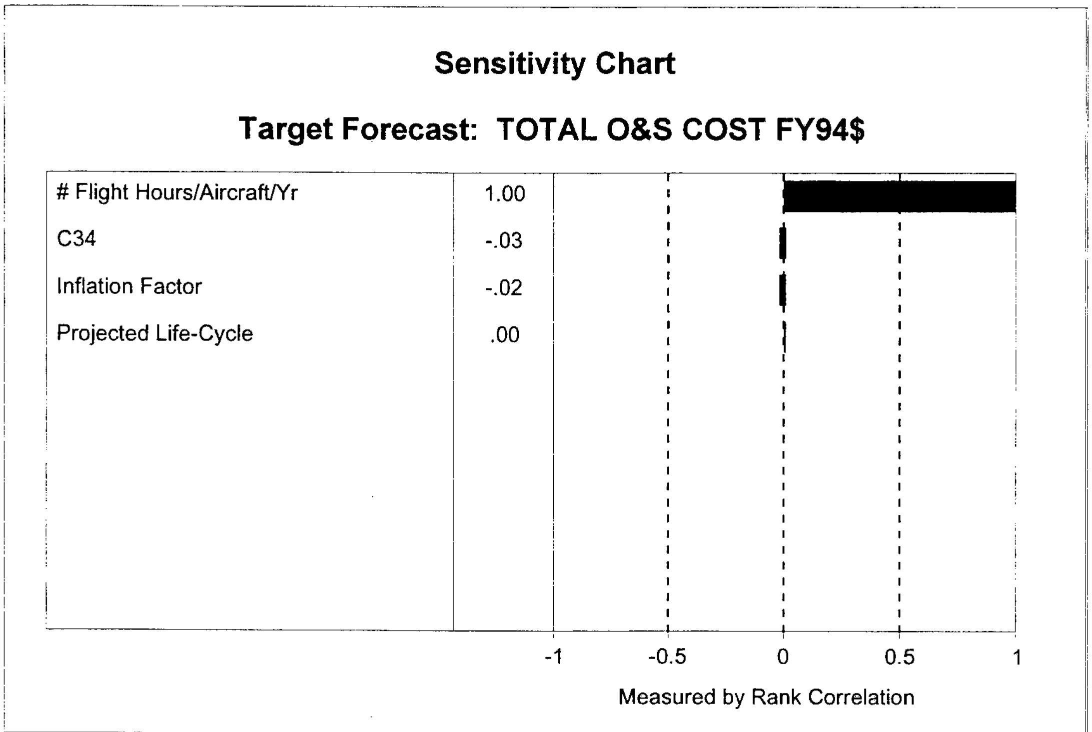
UH-4BN **All Dollar Values in Millions**

	Value	Assumptions
O&S Cost/Flight Hour	$0.01	
# Flight Hours/Aircraft/Yr	334.80	Triangular Distribution, Minimum-0, Maximum-480
Inflation Factor	3.00%	Normal Distribution, Mean-3%, Std Dev-0.3%
Reduced Avionic Vib Save	25.00%	Uniform Distribution, Minimum-0%, Maximum-25%
Projected Life-Cycle	20	Triangular Distribution, Minimum-15, Maximum-25

Items	Year								Year
	0	1	2	3	4	5	6	7	8
O&S Cost/Flight Hour		$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01
# Flight Hours/Aircraft/Yr		334.8	334.8	334.8	334.8	334.8	334.8	334.8	334.8
# of Aircraft per Year		0	6	12	12	12	12	12	12
Cumulative # of Aircraft		0	6	18	30	42	54	66	78
Annual O&S Cost		$0.00	$10.27	$30.81	$51.35	$71.89	$92.43	$112.97	$133.50
Inflation Factor		1.03	1.06	1.09	1.13	1.16	1.19	1.23	1.27
Reduced Avionic Vib Save		$0.00	$0.20	$0.61	$1.01	$1.42	$1.82	$2.22	$2.63
Annual O&S Cost	$0.00	$0.00	$10.07	$30.20	$50.34	$70.47	$90.61	$110.74	$130.88
Inflation Adjust O&S Cost	$0.00	$0.00	$10.68	$33.00	$56.65	$81.70	$108.19	$136.20	$165.79
TOTAL O&S COST FY94$	**$2,490.00**								
TOTAL O&S COST TY$	$3,677.34								

Year					Year					Year	
9	10	11	12	13	14	15	16	17	18	19	20
$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01
334.8	334.8	334.8	334.8	334.8	334.8	334.8	334.8	334.8	334.8	334.8	334.8
12	10	0	0	0	0	0	0	0	0	0	0
90	100	100	100	100	100	100	100	100	100	100	100
$154.04	$171.16	$171.16	$171.16	$171.16	$171.16	$171.16	$171.16	$171.16	$171.16	$171.16	$171.16
1.30	1.34	1.38	1.43	1.47	1.51	1.56	1.60	1.65	1.70	1.75	1.81
$3.03	$3.37	$3.37	$3.37	$3.37	$3.37	$3.37	$3.37	$3.37	$3.37	$3.37	$3.37
$151.01	$167.79	$167.79	$167.79	$167.79	$167.79	$167.79	$167.79	$167.79	$167.79	$167.79	$167.79
$197.03	$225.50	$232.26	$239.23	$246.40	$253.80	$261.41	$269.25	$277.33	$285.65	$294.22	$303.05

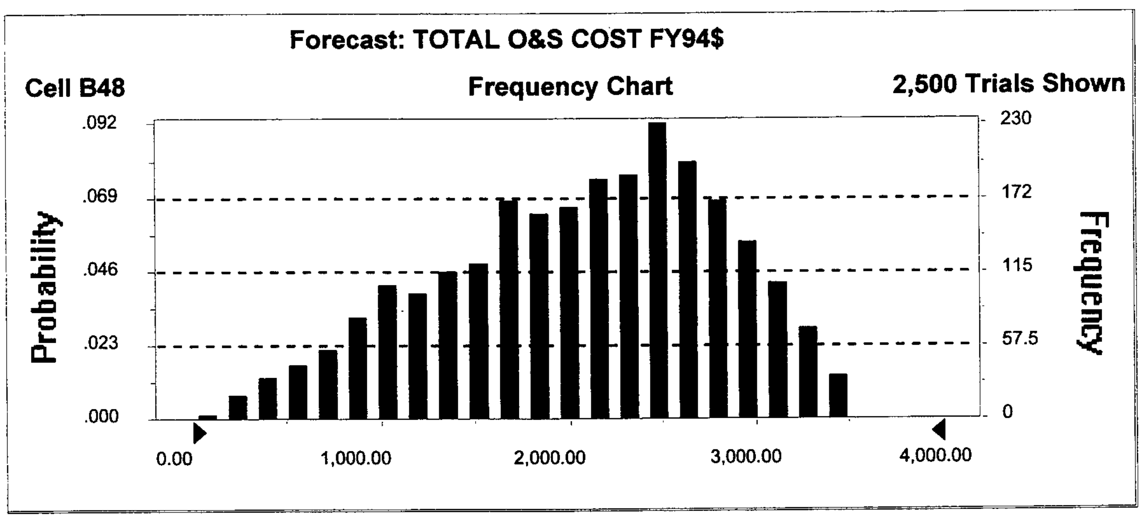
Crystal Ball Report
Simulation started on 12/7/95 at 20:12:51
Simulation stopped on 12/7/95 at 20:15:48



Forecast: TOTAL O&S COST FY94$ Cell: B48

Summary:
Display Range is from 0.00 to 4,000.00
Entire Range is from 113.04 to 3,540.65
After 2,500 Trials, the Std. Error of the Mean is 14.99

Statistics:	Value
Trials	2500.00
Mean	2060.96
Median (approx.)	2145.94
Mode (approx.)	2512.36
Standard Deviation	749.48
Variance	561716.70
Skewness	-0.36
Kurtosis	2.38
Coeff. of Variability	0.36
Range Minimum	113.04
Range Maximum	3540.65
Range Width	3427.61
Mean Std. Error	14.99



Forecast: TOTAL O&S COST FY94$ (cont'd) Cell: B48

Percentiles:

Percentile	Value (approx.)
0%	113.04
10%	983.44
20%	1368.87
30%	1674.95
40%	1915.96
50%	2145.94
60%	2357.41
70%	2539.25
80%	2748.49
90%	2986.52
100%	3540.65

Frequency Counts:

Frequency:

Freq.	Group	Start Value	End Value	Prob.
0		-Infinity	0.00	0.000000
5	1	0.00	160.00	0.002000
19	2	160.00	320.00	0.007600
33	3	320.00	480.00	0.013200
43	4	480.00	640.00	0.017200
55	5	640.00	800.00	0.022000
79	6	800.00	960.00	0.031600
105	7	960.00	1,120.00	0.042000
99	8	1,120.00	1,280.00	0.039600
115	9	1,280.00	1,440.00	0.046000
121	10	1,440.00	1,600.00	0.048400
170	11	1,600.00	1,760.00	0.068000
160	12	1,760.00	1,920.00	0.064000
166	13	1,920.00	2,080.00	0.066400
188	14	2,080.00	2,240.00	0.075200
191	15	2,240.00	2,400.00	0.076400
230	16	2,400.00	2,560.00	0.092000
200	17	2,560.00	2,720.00	0.080000
170	18	2,720.00	2,880.00	0.068000
139	19	2,880.00	3,040.00	0.055600
106	20	3,040.00	3,200.00	0.042400
71	21	3,200.00	3,360.00	0.028400
34	22	3,360.00	3,520.00	0.013600
1	23	3,520.00	3,680.00	0.000400
0	24	3,680.00	3,840.00	0.000000

Forecast: TOTAL O&S COST FY94$ (cont'd)

Cell: B48

Freq.	Group	Start Value	End Value	Prob.
0	25	3,840.00	4,000.00	0.000000
0		4,000.00	+Infinity	0.000000
2500 Total				1.000000

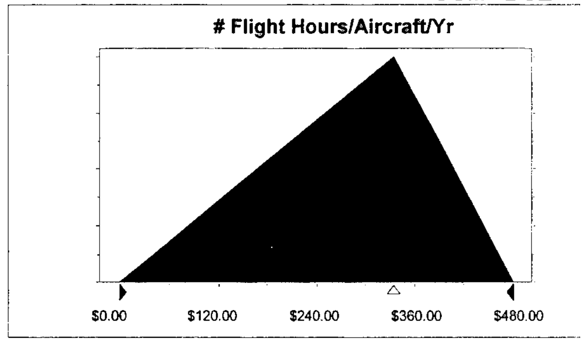
Cumulative:

Freq.	Group	Start Value	End Value	Prob.
0		-Infinity	0.00	0.000000
5	1	0.00	160.00	0.002000
24	2	160.00	320.00	0.009600
57	3	320.00	480.00	0.022800
100	4	480.00	640.00	0.040000
155	5	640.00	800.00	0.062000
234	6	800.00	960.00	0.093600
339	7	960.00	1,120.00	0.135600
438	8	1,120.00	1,280.00	0.175200
553	9	1,280.00	1,440.00	0.221200
674	10	1,440.00	1,600.00	0.269600
844	11	1,600.00	1,760.00	0.337600
1004	12	1,760.00	1,920.00	0.401600
1170	13	1,920.00	2,080.00	0.468000
1358	14	2,080.00	2,240.00	0.543200
1549	15	2,240.00	2,400.00	0.619600
1779	16	2,400.00	2,560.00	0.711600
1979	17	2,560.00	2,720.00	0.791600
2149	18	2,720.00	2,880.00	0.859600
2288	19	2,880.00	3,040.00	0.915200
2394	20	3,040.00	3,200.00	0.957600
2465	21	3,200.00	3,360.00	0.986000
2499	22	3,360.00	3,520.00	0.999600
2500	23	3,520.00	3,680.00	1.000000
2500	24	3,680.00	3,840.00	1.000000
2500	25	3,840.00	4,000.00	1.000000
2500		4,000.00	+Infinity	1.000000

End of Forecast

Assumptions

Assumption: # Flight Hours/Aircraft/Yr Cell: B32

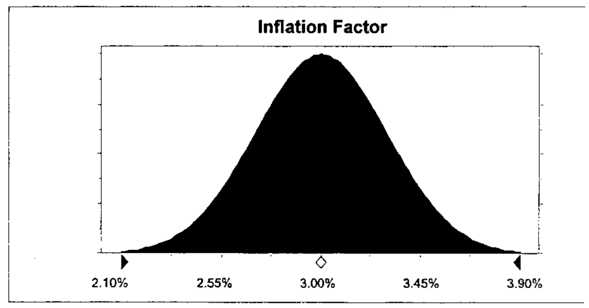


Triangular distribution with parameters:

Minimum	$0.00
Likeliest	$334.80
Maximum	$480.00

Selected range is from $0.00 to $480.00
Mean value in simulation was $274.38

Assumption: Inflation Factor Cell: B33

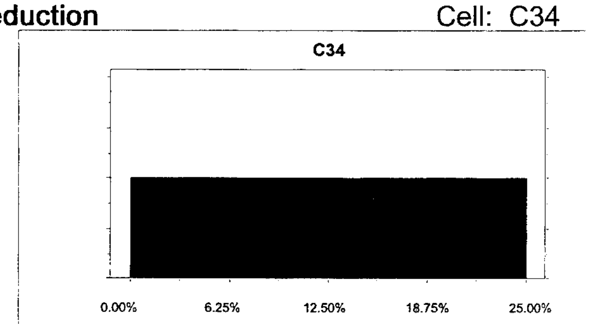


Normal distribution with parameters:

Mean	3.00%
Standard Dev.	0.30%

Selected range is from -Infinity to +Infinity
Mean value in simulation was 2.99%

Assumption: Percent Avionics Vibration Reduction Cell: C34

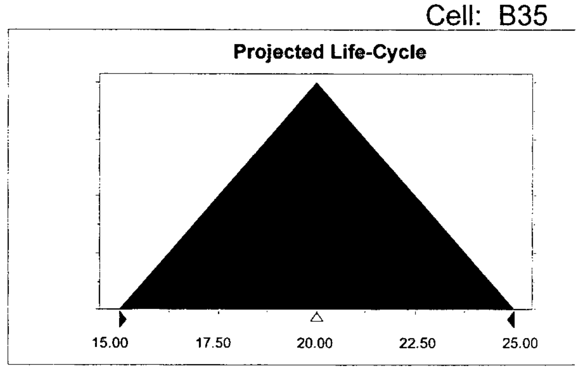


Uniform distribution with parameters:

Minimum	0.00%
Maximum	25.00%

Mean value in simulation was 12.62%

Assumption: Projected Life-Cycle Cell: B35



Triangular distribution with parameters:

Minimum	15.00
Likeliest	20.00
Maximum	25.00

Selected range is from 15.00 to 25.00
Mean value in simulation was 19.95

End of Assumptions

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[4] Ibid.

[5] Funding Data----------------

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[7] Navy Times, 26 December 1994.

[8] Navy Times, 26 December 1994.

[9] Przemieniecki, p. 21.

[10] Ibid.

[11] Ibid., p. 33.

[12] Ibid.

[13] Ibid., p. 22.

[14] Acquisition of Defense Systems/Marine Corps Gazette

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[16] Przemieniecki, p. 27.

[17] Mutter, p. 60.

[18] Przemieniecki, p. 29.

[19] Ibid., p. 205.

[20] Mutter, p. 65.

[21] Przemieniecki, p. 142.

[22] Ibid.

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[30] Integrated Logistics Support Guide, p. 6-2.

[31] Cost Estimating Methodologies, Fact Sheet 2.3, p. 2.3-1.

[32] Integrated Logistics Support Guide, p. 6-3.

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[41] Ibid.

[42] Ibid.

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[54] Ibid., p. 6-9.

[55] Ibid., p. 6-5.

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